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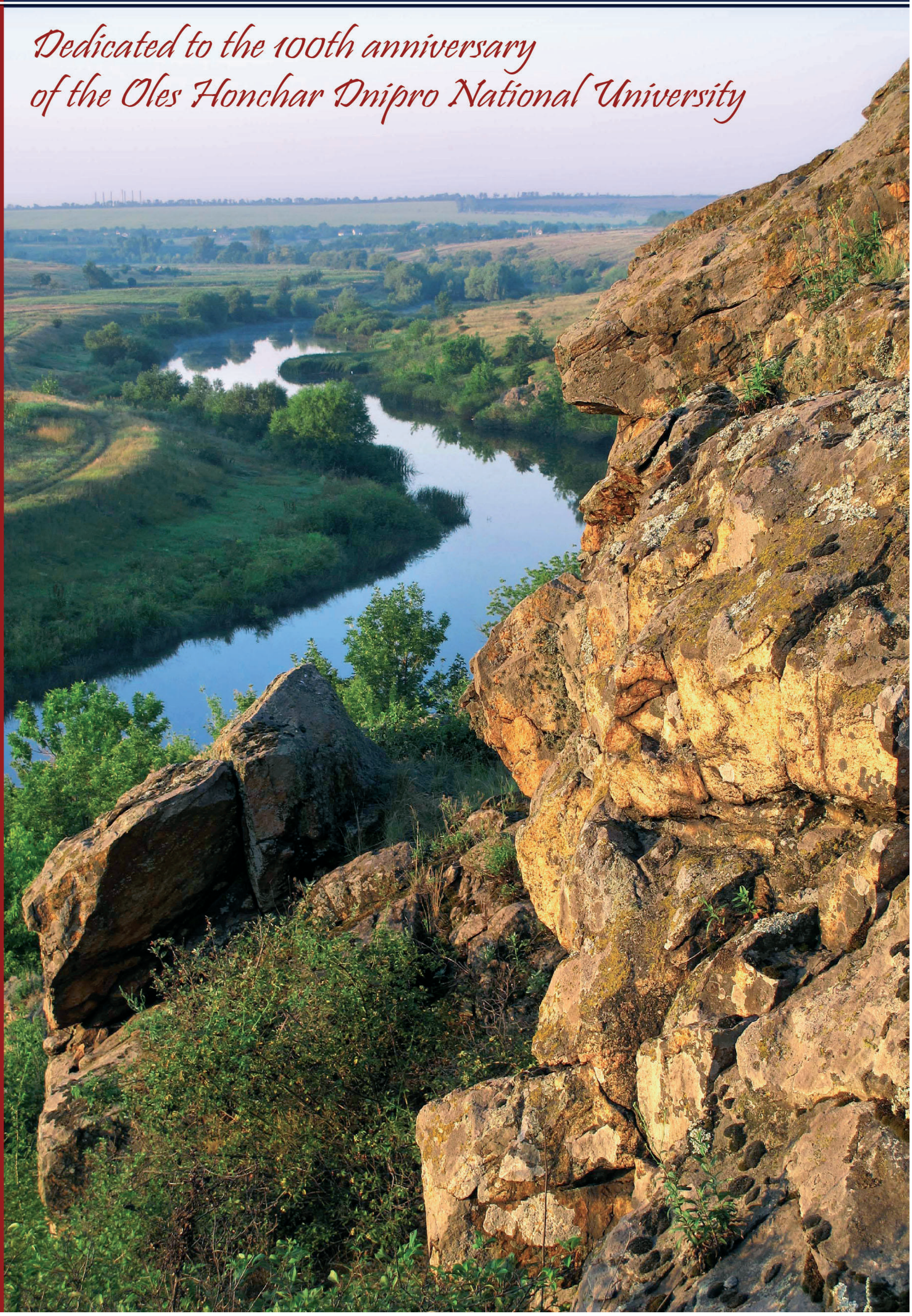

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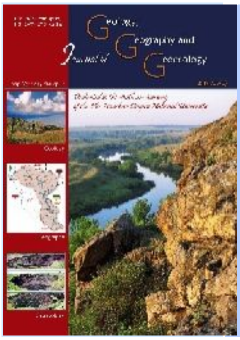

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Post-pyrogenic changes in the properties of grey forest podzolic soils of ecogeosystems of pine forests under conditions of anthropogenic loading

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Abstract. This article presents the analysis of results of experimental data of post-pyrogenic change of soils of ecological systems of pine forests.Ground fires transform the surface organogenic horizons of soils. The negative influence of low-intensity fires of different intensity on the change of humus stock, qualitative fractional composition of organogenic soil horizons and their chemical composition is shown.Post-pyrogenic transformations of physical and chemical soil characteristics are found, which are not simply their corresponding reaction to the pyrogenic effect, but a clear signal reflecting the state of the soil immediately after the fire, taking into account its strength and intensity, and after a certain period of time. There is a certain dependence of the degree of pyrogenicity on the duration of the effect of fire on the soil. The recent influence of a medium intensity fire on the soil is marked by a clear reaction of the complex of its properties.Physical and chemical properties of soils after fires deteriorate: humus burns, the content of nitrate nitrogen decreases.Forest fires sharply change the morphological state of the upper part of the soil profile. The nature of the surface horizons of soils changes, a new pyrogenic horizon is formed, which differs from natural analogues in terms of physical and chemical properties and the content of ash elements. Under the influence of fire there are changes in such properties as: pH, content of exchange cations, gross and moving forms of nitrogen, etc.The heavy metal concentration in surface horizons increases several times and exceeds the background values due to the mineralization of forest litter and herbaceous vegetation from the combustion and subsequent migration of chemical elements , which presents an environmental hazard.The change in the chemical composition of soils can create conditions for the impossibility of the existence of a root ecosystem, its death, and development, after a certain time, of another modified ecogeosystem.

Key words: pine forests, grass fires, biogenic pyrogenic horizons of soils, physical and chemical properties of soils, trace metals.

Постпірогенні зміни властивостей сірих лісових опідзолених ґрунтів екогеосистем соснових лісів в умовах техногенного навантаження

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Анотація. Наведено аналіз результатів експериментальних даних постпірогенної зміни ґрунтів екогеосистем соснових лісів. Низові пожежі трансформують поверхневі органогенні горизонти ґрунтів. Показано негативний вплив низових пожеж різної інтенсивності на зміну запасу гумусу, якісного фракційного складу органогенних горизонтів ґрунтів і їх хімічного складу. Виявлено постпірогенні трансформації фізико-хімічних показників ґрунтів, що є не просто їх відповідною реакцією на пірогенний вплив, а чітким сигналом, що відображає стан ґрунтів, як відразу після впливу пожежі, з урахуванням їх сили і інтенсивності, так і через певний період часу. Спостерігається певна залежність ступеня пірогенності від давності впливу пожежі на ґрунт. Недавній вплив пожежі середньої інтенсивності на ґрунт відзначений чіткою реакцією цілого комплексу її властивостей. Фізико-хімічні властивості ґрунтів після пожеж погіршуються: вигорає гумус, зменшується вміст нітратного азоту. Лісові низові пожежі різко змінюють морфологічний стан верхньої частини ґрунтового профілю. Змінюється характер поверхневих горизонтів ґрунтів, нерідко формується пірогенний горизонт, який за фізико-хімічними властивостями і вмістом зольних елементів відрізняється від природних аналогів. Під впливом вогню виникають зміни таких властивостей, як: рН, вміст обмінних катіонів, валових і рухомих форм азоту та ін. Концентрація ВМ у поверхневих горизонтах підвищується в декілька разів і перевищує фонові значення внаслідок мінералізації лісової підстилки та трав'янистої рослинності від згорання і подальшої міграції хімічних елементів, що являє екологічну небезпеку. Зміна хімічного складу ґрунтів може створювати умови для неможливості існування корінної екогеосистеми, її загибелі і розвитку через певний час іншої модифікованої екогеосистеми.

Ключові слова: соснові ліси, низові пожежі, біогенні пірогенні горизонти ґрунтів, фізико-хімічні властивості ґрунтів, важкі метали.

Introduction. Forest fires cannot be considered one of the main soil-forming factors, but at the same time they have both direct and indirect effects on the formation of soils. The literature contains some studies which prove the significance of pyrogenic load on soils and prove the role of pyrogenic impact on the evolution and functioning of soil in forest ecosystems (Aleksandrovskiy, 2007, Chevyichelov, A.P. 2002, Bento-Goncalves, 2012, Doerr SH & Cerda A. 2005, Krasnoschekov, 2014). Transformation of morphological and chemical properties of soils in pine forests after fires was studied by Shahmatova Y. U. (Shahmatova 2008).

More and more works appear, in which authors consider fire as an important factor in soil formation, which has various effects on the formation of the soil cover in forest ecosystems. At the same time, the pattern and the extent of pyrogenic impact on soil can be different depending on the physical-geographic conditions, type of forest, initial soil properties, and also the type and intensity of the fire.

Some work has also been done on describing the peculiarities of the changes in morphological, physical-chemical and chemical properties of soils of pine forests in the first months after a fire. This research has revealed the changes in morphological structure of forest litter, its density and changes in chemical properties. The formation of soils in a post-fire period is related to the pyrogenic transformation of the organogenic horizons, therefore their changes are indicators of the fire‘s impact on soil. A new diagnostic dynamic organogenic pyrogenic horizon (O_{pir}) forms, which by its physical-chemical properties significantly differs from the natural unchanged analogues. During combustion of the organic substances, large amounts of ash compounds are released from the upper horizons, which automatically changes the reaction of the environment, the amount of humus, content of nitrogen, number of exchangeable cations (Dyimov et al., 2014).

The analysis of the presence of polycyclic aromatic hydrocarbons (PAHs) indicated that the concentrations of chrysene, fluorene, naphthalene, pyrene, and anthracene in the horizon O_{pir}increased significantly compared to the pine forest in the territory unaffected by the technogenic impact. The total content of polycyclic aromatic hydrocarbons (PAHs) in the horizon O_{pir} increased mostly due to the increase in the share of two- and three-nuclei PAHs (naphthalene, fluorene). Mineral horizons of soils in burned areas are enriched with the most mobile amphiphilic fractions of the organic compound, which is manifested in the increase both in total and relative content of hydrophilic fractions which are possibly represented by the products of combustion of plant remains (Dyimov et al., 2014).

Forest fires also cause changes in geochemical peculiarities of ecogeosystems due to the migration via smoke and the further wash-out of the nutrients from the soil, and changes in hydrothermal regime. Change in abiotic conditions leads to transformation of the range and qualities of the ecologic niches in the burned area, loss of structural relationships between the environment and the spatial structure of the soil cover. In such conditions, the previous soil fauna is unable to perform its ecological functions, and the areas damaged by fire can be places where other species migrate to within the ecogeosystem (Gongalskiy, 2015).

The impact of fire on the components of ecogeosystems significantly varies and was studied by a number of researchers, but remains uncertain. Once again, we should mention that the geoecological assessments of the impact of the fires on natural complexes in general are currently absent in the literature. At the same time, there are detailed studies on the effects of the fires on particular components of the ecosystem, or generalized characteristics of post-fire formation of vegetation, which reveal indirect results of this impact. Currently, most results of post-pyrogenic studies focus particularly on vegetation as the most important and dynamic component and indicator of natural complexes. At the same time, various indirect effects of the fires on the environment through post-pyrogenic changes in the content and the structure of phytocenoses can be much significant than the direct effects.

The **objective** of this study was to analyze the post-pyrogenic changes in the properties of soils in the ecogeosystems of pine forests in Kharkiv Oblast in the conditions of technogenic load and assessment of "pyrogenicity" (extent and duration of its manifestation) in the soil.

To achieve the goal, the following tasks had to be solved:

Study the impact of the pyrogenic factor on the main physical-chemical properties of grey forest podzolic soils in pine forests of Scots pine. Determine the peculiarities of transformation of the chem-ical properties of soils affected by the pyrogenic
facor.

Conduct a comparative analysis of the peculiarities of distribution of mobile compounds of heavy metals (HM) in undisturbed soils and in pyrogenic soils.

Material and methods. The formation of soils in the post-fire period is related to the pyrogenic transformation of organogenic horizons, therefore their changes are an indicator of the fire‘s mpact on the soil.

Generally, fires affect all components of ecogeosystems, including their regime of functioning and evolution. A significant role must be played by soil as a lithogenous base for any natural complex.

The plantations which are most severely damaged by the fires are forest areas near large urbanized centers in the conditions of technogenic load. In Kharkiv Oblast, one of such objects of forest area is "Zhovtnevy lishosp" state enterprise of the Kharkiv Oblast administration of forestry and hunting (KOAFH), which is located near Kharkiv. Over the recent years, the area of the fires in the territory of this forest land continues to increase up to 30 ha each year. Therefore, as the object of study, we chose a part of a pine terrace near the Uda river within the territory of “Zhovtnevy lishosp”state enterprise.

For the study, we selected sample (experimental) plots (SP).

SP №1 was a flattened area of insignificantly declined slope of the facies of pine terrace with grey forest podzolic soil under the pine forest dominated by Scots pine (*Pinus sylvestris* L.) and grass-forb association with domination of greater celandine (*Chelidonium majus* L.) in the grass stand, leafy spurge(*Euphorbiavirgata* Waldst.), yellow bedstraw(*Galium verum* L.) and blue lettuce (*Lactuca tatarica* L.). On the plot, there were recorded and clearly seen the signs of fire which occurred 4-5 years ago: pines were affected by the fire up to the height of 1-2.5 m, the forest litter was damaged and in some places, the signs of the sources of fire and the areas with no vegetation were seen. The total area of the fire was around 0.8 ha. The fire which occurred within SP №1 was evaluated as a fire of the first degree for the tree stand was damaged insignificantly. Much more significant damage was caused to the undergrowth and shrub-herbaceous cover.

Sample plot №2 was selected because that area was affected by a forest fire of the third degree ten years ago, and now, the only signs of that fire are some pine trunks burned up to the height of 2-3 m. It is a plot of declined facies with grey forest podzolic soil under the pine forest of Scots pine (*Pinus sylvestris* L.) and domination of grasses (Gramineae). There was sparse growth of Canadian hawkweed(*Hieracium umbellatum* L.), leafy spurge(*Euphorbia virgata* Waldst.) and greater celandine (*Chelidonium majus* L.).

Sample plot №3 is located in 200-300 meters to the south-east of sample plot №1. It has a phytocenotic plant community similar to the sample plot №2. Unlike the previous facies, there are no signs of the fire. Its distinctive characteristic is the presence of intact forest litter of up to 10-12 cm thickness, which consists of dry pine branches, dry needles, strobili (pine cones)and dead remains of grass vegetation.

The grey podzolic soils we studied were the soils of a Scots pine forest with domination of grasses. On SP №1, the forest fire took place in 2013, SP №2 was affected by fire in 2008. After the fires, no pyrogenic impacts were observed in the territory. The last samples were collected in 2018 - 5 and 10 years after the forest fires (Table 1).

On each plot, we collected several samples of soil from the depth of up to 15 cm, and analyzed mean values. For all samples, we determined pH of the water extracted from soil using potentiometric method, content of humus and total nitrogen using Turin‘s method, granulometric composition using Kaczyński‘s method, mobile forms of phosphorus and potassium using Machigin‘s method [Spirina & Soloveva 2014]. The concentrations of mobile forms of heavy metals (HM) were determined using nuclear-absorptional method on a S-115M (*Russian* - C-115M) spectrometer.

Study on the acidity of soils. During the study of acidity of the soils, we determined the following pattern: acidic values of pH were determined for the litter in the old burned area, and pH was closer to the norm in the newly burned area. In general, after the fires, changes of acidity towards alkalinity were observed in the burned areas in organogenic horizons. In soil of newly burned areas, increase in the content of potassium cations in organogenic horizons occurs (Table 1).

The results of the study of acidic-alkaline conditions in the researched soils revealed increase in pH in soils affected by the fires. Therefore, in the control sample of the upper layer of grey forest podzolic soils (SP №1), pH equaled 4.1. In the similar soil of the experimental plot (SP №2), the reaction changed towards alkalinity after the fire (pH = 4.8).

Table 1. Analysis of pH of the soil environment

	year	SP№2*	SP№1**	Control
pH	2008	4.8	-	4.1
	2013	4.6	5,1	4.2
	2018	4.3	4,7	4.2

*The fire occurred on the plot in 2008
**The fire occurred on the plot in 2013

In 2013, there was observed a steep increase in pH of the environment on SP №1. Acidity on the plot slightly increased, but three years after the fire, it was still higher than the values of the control.

In 2018, change in pH towards acidity was observed on both plots. On SP №2, 10 years after the fire, the reaction of the environment practically reached the values of the control.

As a result of the combustion of the litter, pH in the upper layer of 0-10 cm changed towards neutral conditions to 4.8 and 5.1 compared to 4.1–4.2 in the control. The values of this parameter in other horizons were close to neutral.

The tendency towards increase in pH of soils after fires could be explained by the fact that the ash water-soluble compounds, after penetrating the soil, saturate the absorption complex with alkaline earth elements and cause change in the reaction of the environment to the neutral range. An important role in determining the pH values belongs to the time elapsed since an area had burned . In soils of old burned areas, pH values are close to the control, which was also mentioned by other researchers (Gyininova & Syimpilova 1999, Tsibart & Gennadiev 2008).

Physical-chemical analysis of the soils. Favourable conditions for forest growth in the conditions of saturation of soil with main elements up to 50-80%, the content of easily soluble compounds of potassium and phosphorus is higher than 5 mg per 100 g of soil. Pine grows well at absorption capacity of 7-12 mg-equ .At the same time, growth of most tree species becomes inhibited in highly acidic or alkaline soil.

Four-five years after the low-intensity forest fire (SP №1, 2013), the composition and the structure of the surface organogenic horizons changed. During that period, a 3-4 cm layer of litter formed on the surface which was completely burned during the fire. However, on the plots not affected by the fire, this layer composed completely of recently fallen needles, including large needles, bark, reaches 10-12 cm. In the fraction composition, large fragments dominate (brushwood, bark, strobili) - 77.1%. The needles and grass equal 17.5 and 5.3% respectively. The organogenic pyrogenic horizon is 3.6 cm thick.

The analysis of the area after the fire which took place 10 years ago (SP №2, 2018) revealed that the layer of forest litter increased to 5.2 cm. Fraction composition had the following structure: fraction (knots, bark, strobili) – 70%. Needlesandgrassequal 28.1 and 1.9% respectively (Fig. 1).

The soils are characterized by low content of humus in the upper accumulatng horizon. As the depth increases, its content steeply decreases, which is typical for this type of soil, the largest amount of total nitrogen is typical for organogenic horizons (Table 2, Fig. 2). Therefore, the impact of a ground fire causes the humus horizons of grey podzolic soils to respond with loss of nitrogen as a result of its partial combustion in the organic compounds.

A number of researchers indicate that in soils affected by fire, the humus content sometimes increases. This phenomenon can be explained by the intensification of the sod processes after the combustion of tree vegetation, and also decomposition of unburned remains of roots, needles, branches in the first hour after the fire.

In the studied samples, the humus content in the burned areas was lower compared to the control during quite a long period of time.

One of the main sources of organic compound and ash elements for soil is the forest litter. Ground fires lead to partial or complete combustion of forest litter, which further affects the organogenic characteristics of soils, first of all their upper horizons.

The older the burned areas, the lower the values of pH, content of exchangeable cations and humus. This is related to the fact that the reaction of the soil to pyrogenic impact diminishes (Fig. 2).

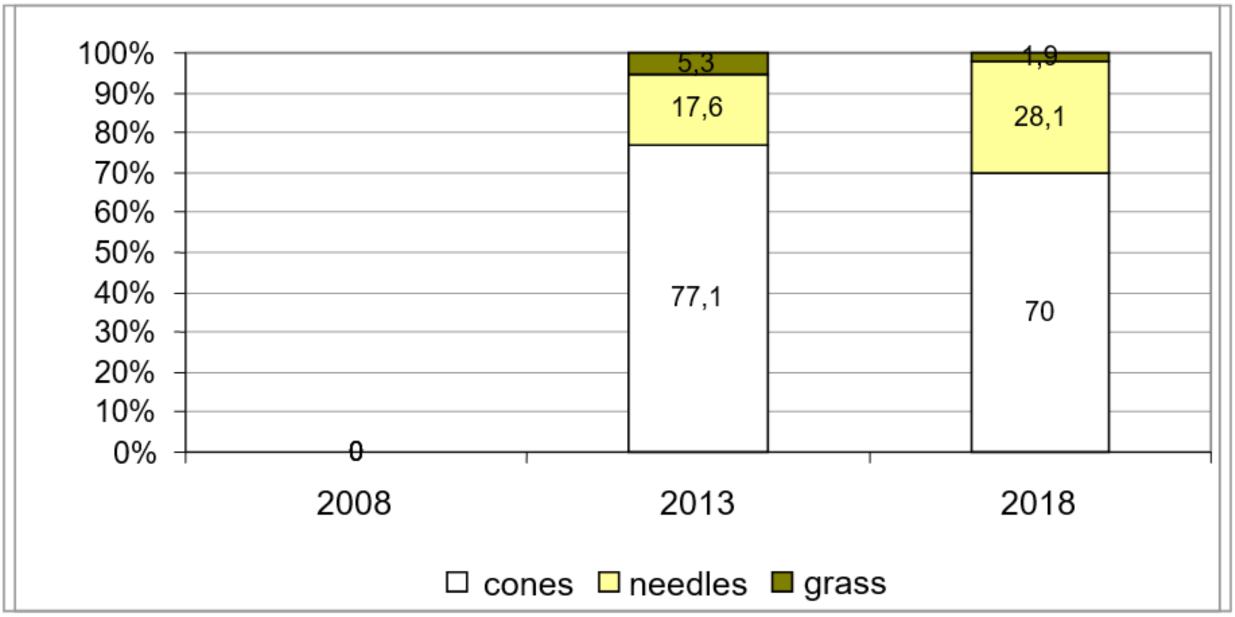

Fig. 1. Fraction composition of forest litter, % (SP №2)

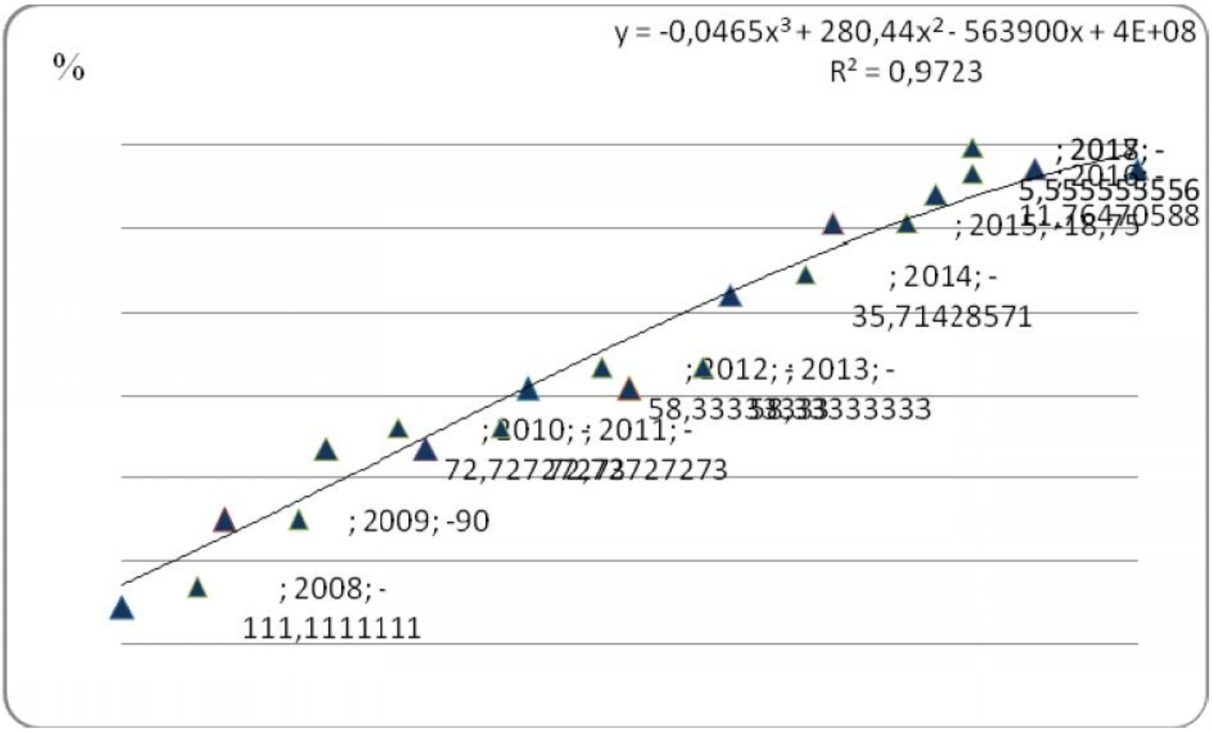

Fig. 2. Decrease in the humus content in the soils after forest fire (SP №1) compared to the control, %

Granulometric composition of grey forest podzolic soils in general is represented by sandy fractions. The content of sand in the horizons ranges from 71 to 97.2%.

The temperature of the ground layer of air in the felled areas of pine forests reaches around 50°C, which often causes death of young plants. A biological feedback occurs between the humidity and temperature of soil. Similarly to humidity, the temperature depends on the exposition of the slopes. As the steepness of the slope increases, the soil humidity in the same types of forests diminishes.

Therefore, the meteorological ecological factors after the fires provide a possibility of natural recovery of the coniferous trees, except for days with high temperature on the soil surface, mostly in summer.

Studying possible changes in the main properties of soils in particular areas of ground affected by fires, the change in chemical properties of soils in pine forests after the fires was proved and named "pyrogenicity of soils" by Y. U. Shahmatova (Shahmatova 2015), indicating the response reaction manifested in change (transformation) of a whole complex of soil properties.

Table. 2 Physical-chemical properties of soil

Parameter		SP№2*	SP№1**	Control
2008				
Exchangeable cations, Milliequivalents /meq./100g of soil	Ca^{2+}	7.2	-	12.6
	Mg^{2+}	4.1	-	7.1
Humus		0.9	-	1.,9
Nitrogen		0.4	-	0.1
2013				
Exchangeable cations, meq./100g of soil	Ca^{2+}	9.2	10.1	12.5
	Mg^{2+}	4.4	5.6	7.0
Humus		1.1	1.8	1.9
Nitrogen		0.2	0.4	0.1
2018				
Exchangeable cations, meq./100gofsoil	Ca^{2+}	10.2	10.8	12.1
	Mg^{2+}	5.6	6.5	7.1
Humus		1.8	0.6	2.0
Nitrogen		0.2	0.1	0.1

*SP №2 was affected by fire in 2008

**SP №1 was affected by fire in 2013 , there are no data for 2008

The literature contains data which prove that after fires, chemical elements accumulatein the soil (Nesgovorova et al., 2014) which in further migrate to the lower horizons of soil and become washed out in neighbouring elementary landscapes or accumulate in the podzolic horizon. This phenomenon can be explained by accumulation of ash elements formed during the combustion of the tree stand. As the alkalinity decreases, the complex compounds of iron, magnesium, silicon, potassium become mobile. In soil, they do not settle, but exist in a form available for the plants and can be consumed by their roots (Nesgovorova et al., 2014).chemical elements

Analysis of the content of heavy metals. According to the obtained data, in soils of SP №1, which was affected by the fire relatively recently, the concentrations of mobile forms of all analysed HM have increased values compared to the soil unaffected by the fire and the soil affected by the fire over 10 years ago. Therefore, Pb content in the upper soil horizon of 0-15 cm increased after the fire by almost 8 times, Ni - by over 6 times, Zn - by 3 times. The concentrations Cu, Cr and Fe increased less significantly (1.7 to 1.1).

We studied the probability of formation of non-soluble or mobile compounds of heavy metals by developing logarithmic concentration diagrams (LCD) (Buts et al., 2018). The heavy metals introduced to the environment can form poorly soluble hydroxides. Also, in the content of soil water, there is a possibility that the metals would form hydroxocomplexes with different amounts of hydroxide ions. The range of sedimentation of hydroxides and the area of prevalence of soluble hydroxocomplexes were studied by developing LCD.

Because the study included a comparative analysis of HM content in the soils of the ecosystems undamaged by the anthropogenic load and their anthropogenic modifications, we used the coefficient of concentration (K_C):

$$K_C = \frac{\kappa_i}{K_i} \quad (1)$$

where κ_i – content of chemical element in the studied object; K_i – content of chemical element in the object of ethalon system.

The indicators of the post-pyrogenic gechemical changes in the studies soils were the results of nuclear-absorption analysis (Fig. 3).

This indicator reflects the extent of the concentration of a chemical element in the studied object or its content in the components of ecosystems in the control.

By the coefficient of concentration, the content of mobile forms of HM in the studied soils of SP №1 andSP №2 are higher than the values of SP №3 in all studied samples. The highest values of $K_C$were determined for Cr, Ni and Pb. Excess in HM concentration in the soils of the studied ecogeosystems, in our opinion, could be caused by technogenic emissions of the industries of Kharkiv and of motor vehicles. There were excessive concentrations of HM in soils of SP №1, which were affected by the pyrogenic factor. This fact should be related to the mineralization of forest litter and herbaceous vegetation, caused by the combustion and further migration of chemical elements in the layers of soil.

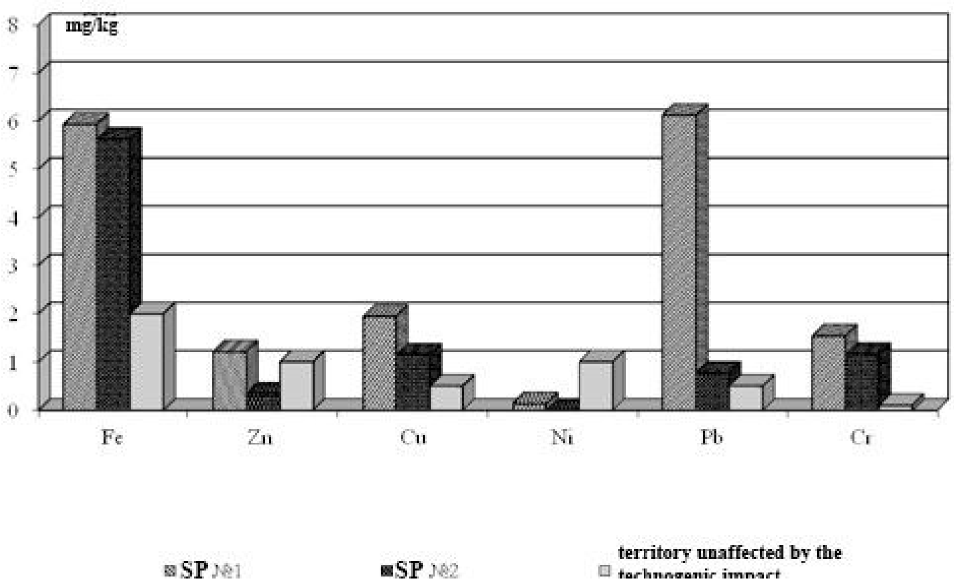

Fig. 3. Content of mobile forms of heavy metals and their values in the control in the soils of the studied ecosystems

In general, taking to account the toxicity of these HM and closeness of the experimental plots to the human settlements, we can state the ecological hazard for the studied ecogeosystems, including hazard for humans.

The results can be used for predicting the geochemical migration of heavy metals in soils as technogenic consequences of disasters caused by pyrogenic factors.

Developing LCD for most microelements (Buts et al., 2018), both necessary for normal viability and growth of plants and heavy metals which can have a toxic effect allows one to predict their migrational ability or ability to accumulate. The range of maximum settlement of poorly-soluble hydroxides is summarised in Fig. 4 Also, we indicated the conditions, in which the heavy metals would have the least solubility in the soil environment, i.e. the conditions, in which their accumulation is the most possible.

In acidic environments (Fig. 4, 5), the solution has ions of Me^{z+}or particles of the type $[Me(OH)_{(z-1)}^{+}]$, in alkaline environments – $[Me(OH)_n^{z-}]$. In acidic soil (4.5 <pH <5.8), all metals, except Fe(II), are present in soluble form and easily migrate and accumulate in plants.

Increase in pH contributes to the fixation of Cd, Co, Mg, Fe(II), Fe(III), Mn, Ni. (Buts et al., 2018).

Conclusions. We found post-pyrogenic changes in physical-chemical parameters of grey forest podzolic soils, which could be considered not only their response to the pyrogenic impact, but a clear signal which reflects the condition of soils both straight after the fire, including extent and intensity, and after a certain period of time. Therefore, there was seen a particular dependence of the extent of pyrogenicity on the age of impact of the fire on the soil. The impact of a fire of average intensity which took place not long ago on grey forest podzolic soils was seen in a clearly manifested reaction of the entire complex of its properties. The soil in the area burned 5 years ago had lower reaction of the studied parameters. If no fire recurs, in 10 years, no signs of pyrogenic impact will be found in the soils.

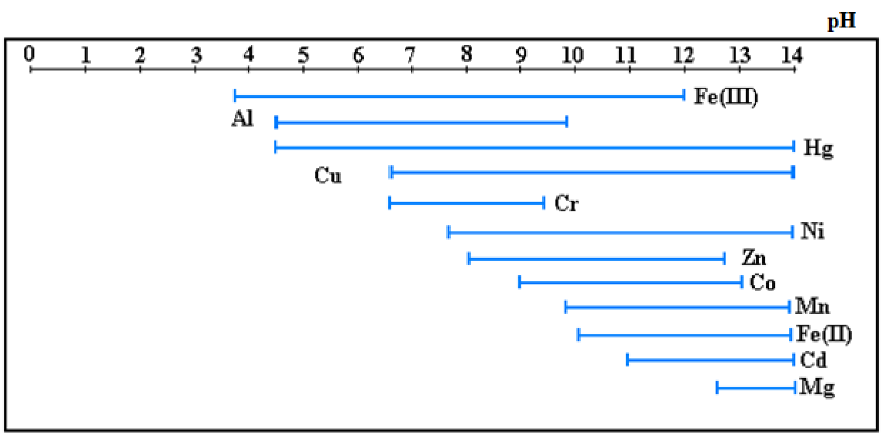

Fig. 4. Range of maximum settlement of hydroxides or hydroxocomplexes of chemical elements

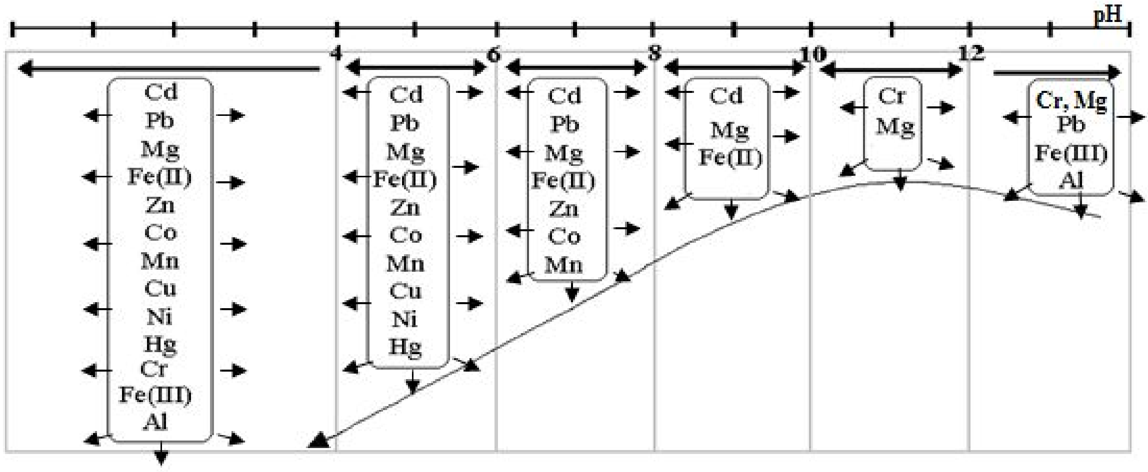

Fig. 5. Migration of the compounds of chemical elements to the environment during changes of pH of soil as a result of fire

Physical-chemical parameters of grey forest podzolic soils after fire decrease because the amount of nutrients in soil decreases: humus burns out, the content of nitrate nitrogen diminishes. The fires, on the one hand, facilitate the penetration of seeds into the soil, but worsen the conditions for growth and development of pines. The content of humus in the upper layer (0-15 cm) of grey forest podzolic soils after a ground fire reduces due to combustion of organic compounds in the upper soil horizon.

Ground forest fires rapidly change the morphological type of the upper part of the soil column. As a result, the pattern of the upper soil horizons changes, in particular, often a new pyrogenic horizon forms, which in its physical-chemical properties and the content of ash elements differs from the natural analogues. The fire causes changes in such properties as: pH, content of exchangeable cations, total and mobile forms of nitrogen, etc. However, it should be taken into account that the behaviour and content of HM in studied soils can be conditioned, apart from the impact of fire, also by geochemical conditions in the region - speed of water migration and biological consumption, relief of the area.

Concentration of HM in the upper soil horizons of pine forest terraces increases several times and exceeds the control parameters due to the mineralization of forest litter and herbaceous vegetation caused by combustion and further migration of chemical elements, causing an ecological hazard.

Further study on the changes in the properties of soils caused by the pyrogenic factor has a significant theoretic and practical significance for developing scientific approaches to recovering ecogeosystems after the fires.

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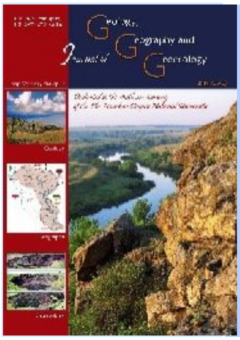

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Labile technogenic geological system of the flooded Shevchenko salt mine (Ukraine)

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Abstract. This paper presents the analog ecological-mining-geological model of the labile technogenic geological system created at the Shevchenko flooded salt mine area within Artyomovsk rock salt deposit, which is the largest rock salt deposit in Europe. Description of all the system elements taking into account their interconnection and interaction are presented on the basis of the analytical processing and compilation of basic mining and geological data as well as the results of the long-term complex ecological-mining-geological monitoring.The paper describes both the geology of the mine area and the condition assessment of the mine including its shape, parameters, and layout. In addition, scientific interpretation of the mechanism of multi-act intrasystem destructive processes, which have been taking place in the last few decades are provided. Natural and technogenic factors determining the development of the created technogenic geological system (such as man-made karst and critical geomechanical deformations) are summarized and analysed. Predictive evaluation of the time-dependent deformation processes development has been carried out using theexisting methodology for assessing the geomechanical condition of the mined-out area of the salt massive. Correctness of the method for evaluation of stability of the unsupported workings system currently in use for the Artyomovsk rock salt deposit development has been confirmed. This work concerns the scientific problems of maintenance of the geo-ecological safety in the densely populated areas disturbed by underground salt mining. Hereinabove research results add information and analytical base to improve the deformation control system for ductile salt layers in various dynamic conditions of man-caused and natural loads. It is shown that such control is required for the aim of reduction of environmental risks and ensuring the safe operation of salt deposits, salt resources protection as well as infrastructure objects at the Earth's surface nearby sites of modern salt mining activity.

Key words: rock salt, salt mine, destructive processes, deformations, Earth's surfacesubsidence,monitoring

Лабільна техногенно-геологічна система території затопленного соляного рудника Шевченко (Україна)

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Анотація. У даній роботі представлена аналогова еколого-гірничо-геологічна модель лабільної техногенно-геологічної системи, створеної на території затопленої соляної шахти імені Шевченка в межах Артемівського родовища кам'яної солі, найбільшого родовища солі в Європі. На підставі аналітичної обробки і компіляції первинних гірничо-геологічних даних, а також результатів тривалого комплексного еколого-гірничо-геологічного моніторингу представлено опис всіх елементів системи в їх взаємозв'язку і взаємодії і дано наукове тлумачення механізму багатоактних внутрішньосистемних деструктивних процесів, що протікають протягом декількох десятиліть. Узагальнені та проаналізовані природні та техногенні фактори, що визначають розвиток створеної техногенно-геологічної системи (техногенний карст і критичні геомеханічні деформації соляного масиву). Виконана прогнозна оцінка розвитку деформаційних процесів з використанням існуючої методики оцінки геомеханічного стану відпрацьованої ділянки соляного масиву. Підтверджено коректність застосовуваної методики оцінки стійкості системи незакріплених виробок при розробці Артемівського родовища кам'яної солі. Робота зачіпає наукові проблеми забезпечення геоекологічної безпеки в густонаселених районах, порушених підземним видобутком кам'яної солі. Викладені результати досліджень поповнюють базу інформаційно-аналітичного забезпечення системи управління деформаціями пластичного розчинного середовища соляних товщ в різних динамічних режимах техногенних і природних навантажень для зниження екологічних ризиків і забезпечення безпечної експлуатації родовищ солей, охорони соляних ресурсів, а також об'єктів інфраструктури на земній поверхні поблизу ділянок сучасної розробки кам'яної солі.

Ключові слова: кам'яна сіль, соляна копальня, деструктивні процеси, деформації, осідання поверхні, моніторинг

Introduction. Problem setting. Deep scientific investigation of the geological-environmental strain due to man-made intervention into salt strata is a matter of concern for present day salt mining practice. It is caused by the growing multilateral interest in salt strata both as a raw material base for rock salt extraction and as an environment for various engineering objects creation such as hydrocarbon and waste storage facilities (including radioactive ones), speleosanatoriums, touristic objects, etc.

A generalized task of many contemporary studies concerning salt deposits is the enhancement of the theory of environmentally acceptable man-made intervention into salt strata. Some important tasks of the environmental safety and commercial goals are in conflict, in particular as it relates to the technical requirements for a reasonable permissible recovery ratio of minerals (rock salt). Particularly an acute issue is finding one of the correct methodology for controlling the rate of strain in salt rocks at all stages of technogenic interference for ensuring their safe level. This research direction is considered to be of high significance for the salt mining activity within densely populated territories since uncontrolled deformations can entail any serious ecological and economic damage endangering the important objects of social and economic infrastructures and people's lives.

All aspects of technogenic deformations of the rock massif and their adverse ecological impact are the separate theoretical and practical issues aimed at developing a system of integrated control and forecasting of these deformation processes.Different scientist around the world has devoted their works to these issues. Salt massifs' geomechanics and physical-mechanical properties of rock salt determining geomechanical processes are considered in the works of Michael L. Jeremic and Saeed Nazary Moghadam (Canada), A.A. Baryakh and V.A. Asanov (Russia), Alla R. Seraya (Ukraine) and many others. Issues of the natural and technogenic karst are detailed in the works of G.V. Korotkevich (Ukraine), Anthony H.Cooper and F. Gutiérrez (Great Britaine) and others. Interaction of different aspects of strain manifestation and consequences as well as monitoring results for deformable areas influenced by the technogenic object created inside salt strata are presented in the works of T.G. Brooks, N. J. o'Riordan and Jamie K. Pringle (Great Britain), Dmytro P. Khrushchov (Ukraine), Mihaela Toderas (Romania), Gloria Desir (Spain), Astrid Gessert and Thomas Schicht (Germany), M. Cała and A. Tajduś (Poland), M. Karimi-Jafari and Pierre Berest (France), Bill Shefchik (USA) and others.

It is important to analyze a significant number of examples of deformation processes development associated with the construction and exploitation of various objects in salt strata in order to create the correct system of salt massif deformation control. Though the manifestation of the destructive processes and land degradation are different in every case, because of the various geological and hydrogeological conditions and various technology applied, it reveals similarities in similar technogenic geological systems (further in the text – TGS).

There is insufficient complex research results dealing with salt environment deformations and the Earth's subsidence monitoring on the territories of man-made objects within salt massifs. Based on long-term monitoring, this work provides a detail description of the active deformation processes and concomitant ecological changes ongoing within the area of old flooded Shevchenko salt mine that exploited the thickest bed of the Artyomovsk rock salt deposit.

The objective of the paper is to present analog model of the technogenic geological system (TGS) of the Shevchenko flooded salt mine area and to interpret mechanisms and factors of its development.

As already mentioned in general, the significance of the work is related to the need for further development of the risk control methodology related to technogenic interference in salt massifs associated with new technologies, to achieve a balance between scientifically based technical requirements and commercial benefits (Brooks et al, 2006).

But the performed research urgency is further strengthened due to the fact that this flooded mine is located in the central part of the modern operation field and its location is adjacent to such an important infrastructure facility as the railway (110 m). A safety pillar with reasonable thickness detaching the flooded mine workings from today operational areas of mine # 4 has been left around this old mine.

It should be noted, there is one more reason of this paper urgency at popular science level. The fact is that some media (including Internet-sources) have presented salt lakes above the flooded salt mine as a certain anomalous zone and have included it in numerous lists of mystical zones of Ukraine. This point also requires the scientific clarifications.

Geological and hydrogeological settings. The geology and hydrogeology of the Artyomovsk rock salt deposit is known quite well. In geological and structural terms, it is located within Bakhmut basin of the Dnieper-Donetsk depression. The geology of the deposit is simple: it is composed of a few subhorizontal rock salt beds belonging to Slavyanska suite of the Lower Permian salt-bearing formation (P1sl) and it is confined to the salt-bearing suite lying closest to the Earth's surface (from 69 m to 600 m).

Slavyanska suite (P_1sl) includes a complex of-characteristic evaporitic sediments (26 rock salt seams, anhydrite and gypsum layers) rhythmically intercalated by carbonate rocks (limestone, dolomite, marl) as well as terrigenous rocks (argillite, siltstone). The salt-bearing suite is monoclinal, dipping north or north-west at 2 – 5°. The thickest industrial beds are named (from the bottom to the top): Under-Bryantsevsky Bed (UBB) with thickness of about 31 m, Bryantsevsky Bed (BB) with thickness up to 41.2 m and Above-Bryantsevsky Bed (ABB) with average thickness of 31.9 m. Now only two beds with the highest industrial quality (BB and UBB) are being extracted.

The geological section of the salt-bearing lavyanska suite, in its upper part is inconsistent stratigraphically. Slavyanska suite sediments are covered by *Kramatorska suite* of the Lower Permian (P_1krm, chemogenous deposits: gypsum, anhydrite), *Dronovska suite* of the Lower Triassic (T_1dr, predominantly terrigenous sediments: siltstone, mudstone, largely fractured sandstone) and Quaternary sediments (loess-like loam, red-colored clay, alluvial deposits of river-valleys with common thickness from 5 to 40 m).

Due to weakly-inclined bedding and unconformity all salt beds contact the water horizons in overlying rocks at the outcrops below the overburden. At the sites of this contact leaching zones of ribbon-like shape are formed (Fig. 1). They are represented by ancient and modern leaching breccia, which is loose and cavernous and, subsequently essentially water permeable. The hydraulic connection between underground mining workings and the leaching zones is extremely dangerous since it irrevocably lead to the development of a deep man-made karst and finally flooding of the mine (Bosevska and Mishchenko, 2009).

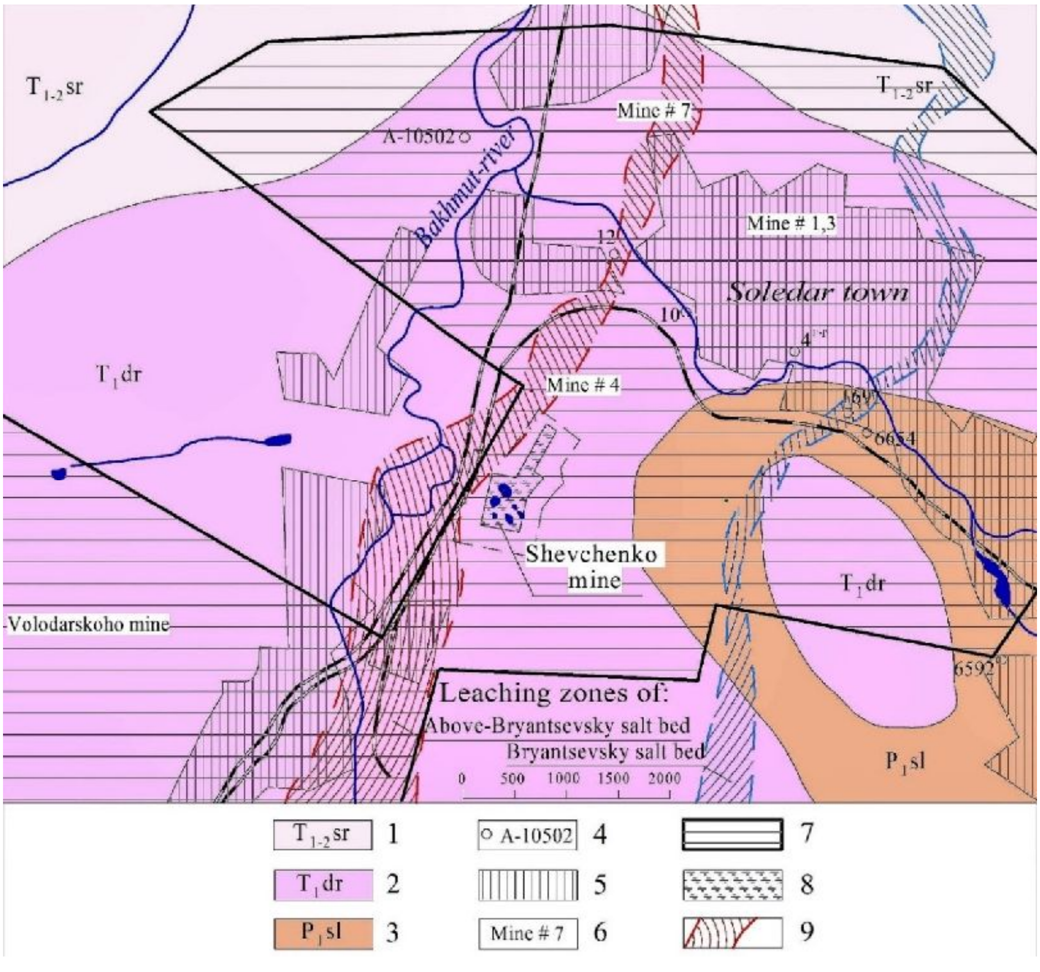

Fig. 1. Geological map of the Artyomovsk rock salt deposit mapping the flooded Shevchenko salt mine and modern mine working fields
1 – Serebryanska suite (undivided Lower and Middle Triassic): sandstone, argillite-like clay; 2 – Dronovska suite (the Lower Triassic): sandstone, siltstone, mudstone; 3 – Slavyanska suite (theLower Permian): rock salt, anhydrite and gypsum with a subordinate amount of carbonate rocks (limestone, dolomite, marl), argillite, siltstones; 4 – exploration wells; 5 – inhabited areas; 6 – operating modern mines; 7 – modern mining area stated by the special permits for subsoil use of State Enterprise "ARTYOMSOL"; 8 – flooded mine workings of the Shevchenko mine; 9 – leaching zones of salt beds defined by exploratory works in 1988 – 1991

The hydrogeology of the deposit is also simple for interpretation: the thick salt massive is a regional impervious bed. All over-salt rock mass is an unified areally, but not uniform aquifer complex that contains the hydraulically connected water horizons from the upper part of the Slavyanska suite to the Quaternary aquifers. Reservoir rocks for the aquifers are the salt leaching breccia (Fig. 2), karstgypsum, fractured sandstones as well asQuaternary sands and loams. According to hydrodynamic characteristics, all aquifers are confinedandunconfined. Some aquifers have the heads of 50 meters and more. Prior works have establishedcontinuous hydraulic connection between all aquifers within local sites. The main direction of pressure flow of water is from the bottom upwardsup to Quaternary aquifers.

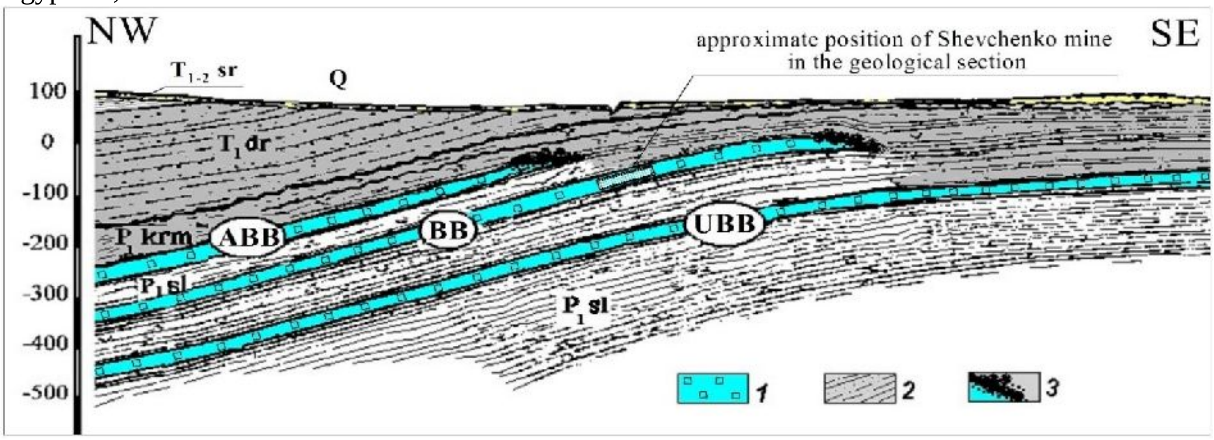

Fig.2. Schematic cross-section of Artyomovsk rock salt deposit (PSA "Donbassgeology", 1988)
(the vertical scale is five times less than horizontal one)
1 – industrial salt beds: Bryantsevsky bed (BB), Under-Bryantsevsky bed (UBB), Above-Bryantsevsky bed (ABB); 2 – water-flooded terrigenous and terrigenous-chemogenic strata (clay, sandstone, argillite, gypsum, anhydrite) (T_1dr, P_1krm); 3 – leaching zones of the salt beds; 4 – Quaternary sediments.

Due to the presence of soluble rocks in geological profile, the chemical composition of groundwater varies widely. The most mineralized waters come from the leaching zones of salt beds (up to 250 g/l and more) and gypsum layers groundwater. The chemical composition of the water of interconnected aquifer complex is sulphate-chloride calcium-sodium or chloride calcium-magnesium-sodium.

Geological conditions predetermine the non-point natural leaching process of upper salt bed (ABB) in some parts of the deposit and natural gypsum karst processes in over-salt rock mass.

Historical background on functioning of the Shevchenko mine. The Shevchenko mine is one of the oldest underground mines that have been established in the Artyomovsk rock salt deposit since 1882. It is located at the right bank slope of the Bakhmut River valley near Soledar town; it is 1.2 miles from Kudryavka railway station.

The location of this mine was chosen spontaneously without geological foundationsdue to the lack of the necessary geological and hydrogeological data during the period of pre mining operation. As a result, the mine operating conditions were dependent on a random factor. Two mining shafts of 170 m depth turned out to be located near the modern leaching zone of the overlying ABB. During the construc-tion, the mine shafts crossed two water-abundant aquifers: 1 – aquifer of Dronovska suite gypsum (depth of 28.3 m, yield of 64.3 m^3/hour); 2 – aquifer of Slavyanska suite gypsum and of the leaching zones of ABB (depth of 89.5 m, yield of 3.8 m^3/hour).

Waterproofing works in the shafts were not performed properly, so the rock salt extraction was carried out under the condition of constant water drainage. Therefore, the mining was accompanied by increasing inflows of water to the shafts; and the total amount of incoming water reached 1560 m^3/day. Incoming waters did not reach salt bed, because the water was captured in different ways, by using a specially constructed drainage system in the shafts. Fresh water was discharged to surface waterswhile brines were directed into the special settling basins on the surface.

The mine exploited the Bryantsevsky bed lying at a depth interval of 120 – 180 m.Salt extraction reached 450,000 t/year. Mining works were carried out using classic room-and-pillar system with remnant support pillars. The following mining system parameters were applied: chamber sizes 15 – 17 m (width) × 23.5 – 33 m (height) × 300 – 600 m (length) and very long interchamber pillars (rib pillars), which has the width of 9 – 12 m.

The overall minefield was 1100 m long and about 350 m wide. The total volume of mining workings reached 5.2 mln m^3 and the floor of workings was 200.000 m^2.

The mine had been functioning for almost 60 years. In autumn 1941, due to military operations of the Second World War, the mine stopped working and drainage was forcibly terminated. From that time, the uncontrollable flooding of the mine with fresh and salty waters began, that resulted in a rapid uneven development of the deep salt karst. In places of fresh water inflow,pillars bases were "undercut" by leaching and the pillars quickly lost bearing capacity.

A year later, the first concentric cracks appeared on the Earth's surface near the shafts and later multiple small concentric craters, which testified to the beginning of the process of the rock mass total destruction over the mine workings.

Over the next 8 years, the destruction of the rock massif over the flooded mine workings and the Earth's surface degradation developed very dynamically. By 1946 the Earth's surface over the mine transformed into numerous predominantly concentric terraces framing multiple smalldips, sinkholes and collapse pits of different morphology, unevenly distributed over the area. Collapses constantly changed shapes and sizes, small dips merged forming depressions of huge areas. The maximum surface destructions occurred in the north-western part of the minefield where the shafts were located. The largest joint ellipse-shaped sinkhole with dimensions of more than 250 m (this is the collapse crater # 1 on the contemporary maps) has been created in this site (Fig. 3). The formed large cavity swallowed up the heapstead buildings, facilities, and equipment including the electrical substation.

Fig. 3. The modern air photo of the flooded Shevchenko mine area (https://map.online.ua/)

After completion of flooding, during the period from 1950 to 1970, the cracking processes on the surface were initiated with gradual decrease in speed with increasing time intervals. The deformations were gradually stabilizing in the next 25 years. They showed themselves in uneven subsidence of the certain surface sites. It led to a change in the outlines of the existing collapse pits.

In 1995 (54 years after the beginning of the mine flooding), against the conviction of the relative stabilization of the geomechanical strain, sudden (momentary) collapse of Earth's surface over the north-eastern part of the mine field occurred result-ing in the huge cylindrical sinkhole with depth about 30 m and with vertical walls (collapse pit # 6, see Fig. 3). The latest collapse pit (# 7) was formed in 2012. Salty or saltish lakes arose in all sinkhole craters in different time. The exception is only collapse pit # 6 located at the elevated terrace. Currently, the entire area above the minefield is in the state of uneven intense deformation condition.

Material and Methods. Synergetic principles (Khomenko, 2007) in reference to modern methodological approaches to ecologically secure man-made intervention into salt massifs have been used for evaluation of today's conditions of the Shevchenko salt mine TGS (technogenic geological system). The main methodological principles of the correct exploitation of salt massifs and evaluation of the consequences of the incorrect one have been vividly discussed in the current scientific literature (Jeremic, 1994; Karimi-Jafari et al, 2008; Bosevska, 2010; Khrushchov et al, 2010; Moghadam, et al., 2012; Mechanical, 2012; Khrushchov and Bosevska, 2014; Toderas, 2013; Kortas, 2014 and others). The views of scientists from different countries do not have significant contradictions, but only complement each other and have several aspects focusing on the specific problems of this area. The international experience of assessing the consequences of salt mines flooding shows general regularity of disturbances in the geological environment and trends in the deformation process development on the Earth's surface. At the same time, different geological features of the territories and mining technical conditions for the construction of various engineering facilities determine the formation of various TGS (Tenison, 2016).

Shevchenko salt mine TGS is presented as the analog ecological-mining-geological model, which adequately reflects all the elements of this system, including the identified processes and phenomena occurring within the system, their interrelation and development, as well as the interaction of the system with external factors.

In order to develop the model, classicalmethodsof background analysis were applied:

- compilation of data from all types of ecological-geological works carried out on the territory, and data on methods and technology of the deposit exploitation (Bosevska and Mischenko, 2009; Bosevska, 2010; Khomenko, 2007; Yeschenko et al, 2011);
- qualitative evaluation of the functional properties of rock salt, first of all, its protectability from technogenic karst (Cooper, 2002; Gutiérrez et al, 2008; Khrushchov et al, 2009, 2010);
- assessment of the long-term geomechanical stability of mine workings system within salt bed, based on proven calculation methods (Savchenko and Seraya, 1970; Baryakh et al, 1996; Asanov, 2010; Metodicheskie, 1997; Moghadam, 2012);
- analysis of the results of prolonged local complex ecological-mining-geological monitoring (Lee and Sakalas, 2001; Brooks et al, 2006; Korolyov, 2007; Shefchik et al, 2011; Pringle et al, 2012; Gessert, 2013; Cała et al, 2017; Desir, 2018);
- ecological audit: identification of geological environment disturbances caused by salt massif deformation; ecological risks evaluation and forecasting (Cooper, 2002; Khrushchov et al, 2010).The data for model development are as follows:

1 – the results of the series of the geological exploration, hydrogeological, karstological and geophysical studies (PSA "Donbassgeology", the Ukrainian Salt Research Institute (USRI)) performed in the 1980s and 1990s due to the urgent need to assess threats to infrastructure, namely: of the nearby railway section;

2 – the results of the integrated monitoring conducted by the USRI from the early 1980s including geomorphologic, hydrogeological (terminated after the stabilization of the hydrogeological situation), hydrological and geomechanical observations.

Hydrogeological works had been performed in a net of deep paired observation wells with a full cycle of experimental work (17 wells in total).

Geomechanical monitoring is a traditional instrumental tracking of the Earth's surface subsidence using the system of ground levelling marks oriented along the observed levelled lines. This type of work is being carried out annually since 1965 (since 1994 frequency is two times a year). The installation of instrument tracking lines, the volume and composition of annual observations are periodically adjusted and regulated by a number of normative documents and recommendations.

The basic postulate for assessing the situation and interpreting all initial data is the following proved tenet: geological environment straining always accompanies the creation of engineer facilities in salt massifs. The main factors for assessment of the strain are geomechanical and hydrogeological implying the development of man-made karst (Bosevska, 2010).

Deformations associated with salt karst can develop only in the unprotected, from the aggressive waters penetration, parts of the salt massif (Khrushchov et al, 2009). The rate and trends of these deformations are important in understanding the salt karst theory (Korotkevich, 1970).

The multi stage geomechanical deformations always take place during the transition of salt massifs into a strained-deformed state due to high plastic properties and specific rheological characteristics of rock salt. The mechanical behavior of rock salt in a strained state is very complex because of its tendency to flow or creep when subjected to a shear stress. Rock salt creep property research has been the subject of a large number of studies (Pfeifle and Senseny, 1982; Jeremic, 1994; Mechanical, 2012; Cała, 2017 and others). As is well known, rock salt responds on loading with different creep rates (transient or steady) in a manner nearly equivalent mechanically dependent upon the deformation stage and the pillar loads. The creep rate may be large enough. The consequence of creeping is gradual compression of the bearing pillars in situ (reduction of their height and dilatancy), the inherited shifting of the entire over-salt rock mass and the subsidence of the Earth's surface. At the last stage of plastic deformations, creep is characterized by accelerating creep rates and, finally, rock salt pillar failure by rupture. In plastic deformation, the continuity of the deformed pillars is maintained; in ruptural deformation, bearing pillars is broken; a pillar failure occurs and the TGS loses its continuity and stability. It may result in significant disturbances of the geological environment, degradation of the Earth's surface with the corresponding threats to the condition of terrestrial objects and the ecological balance of the territory overall (Brooks et al., 2006; Khrushchov,2014).

Taking into account the unique properties of the salt environment and its ability to change during the change of external factors without fracture, the stable condition of the TGS is the state of slow safe plastic deformations of the salt mass without disturbing its continuity, resulting in a slow safe subsidence of the Earth's surface (several mm per year). The areas of the geological environment, which have lost integrity because of the development of destructive processes, are unsuitable for further use. Destructed parts of salt massif and adjacent geological environment are excluded from being further used.

Results and Discussion. The ecological-mining-geological model of Shevchenko salt mine's TGS. This TGS is composed of four large interconnected elements: 1 – part of the salt bed (BB) containing the mining workings; 2 – the geological environment above the mine workings and within the zone of the influence of mine workings; 3 – Earth's surface over the mine field; 4 – surface waters represented by lakes in sinkholes (collapse craters).

The part of the salt bed (BB) containing the mining workings. It includes 3 elements: 1 – void space (mine workings filled with brines); 2 – load bearing pillars of rock salt; 3 – intact salt mass surrounding the mine workings.

1. Mine workings are located at a depth of more than 120 m (up to the roof) and are mostly destroyed. To date, some mine workings are filled with over-salt rocks caved in the worked-out rooms. The rest of the underground space of the mine workings is filled with saturated chloride sodium brines of mineralization up to 320 g/l being in congestive regime. Obviously, in the stable rooms, the cushions of trapped air are created at the roof. Since the roof of the flooded rooms is approximately 50 m below the active water exchange zone, under the hydrogeological circumstances, mine brines cannot be involved in the active groundwater movement; and expansion of mine workings contour in terms of karst is impossible even hypothetically. This is confirmed by the results of performed geophysical studies.The hydraulical connection of the saturated mine brines and upper aquifers is one-way: the brines can penetrate the collapse cracks and enter into the upper aquifers due to extrusion during rock collapse.

The flooding of the mine took a long time. The ratio of the volumes of mine workings and known indicators of water inflows make it possible to estimate that the mine flooding lasted about 10 years at least. Flooding occurred by fresh and salty waters through the mine shafts with a stable hydrogeological regime of incoming water, as the supplying aquifers had relatively stable hydrodynamic and hydrochemical parameters.

A feature of the flooding was the differentiation of the incoming water: fresh water was mainly flowing along the main shaft # 1, while the salty waters of the leaching zone came mainly along the shaft # 2. It led to the development of rapid technogenic karst and leaching of the pillars bases (undercutting them) near the shaft # 1 and the loss of their bearing capacity. Therefore, the first sinkhole around the main shafts was formed a year after the beginning of flooding.

At once, the mineralization increasing of incoming fresh waters occurred directly near the mine shafts; and salty waters flowed the other parts of mine field. Thus, in general, for the most part of the minefield, the flooding regime is defined as a gradual, uniformly time-based rise in the level of saltish water at a rate corresponding to the linear dissolution rate of rock salt (Cherevko, 2006).

USRI investigated the influence of such flooding regime on the state of mine workings and on the bearing capacity of the pillars after the completion of flooding by the means of mathematical modeling by the finite element method and modeling based on natural materials (rock salt of the Bryantsevsky bed).

The results of complex modelling showed the following: in the flooding process, uniform leaching of the lateral surface of the pillars took place; the depth of leaching penetration into the pillar massif did not exceed 10% of its width. As a result, an insignificant change in strain tensor in the elements of the bearing structure occurred: vertical stresses increased by 6%, horizontal stresses increased by 1.5 – 2.0%, maximum tangential ones increased by 3%. In contexts of a slight decrease in the pillars width and a slight increase in strains, the calculated strength of the massif decreased by approximately 15%, which could lead to a decrease in the bearing capacity of the structure. However, the study of the influence of saturated brine on the pillars bearing capacity after completion of flooding showed a significant increase in horizontal stresses while maintaining the distribution pattern of the vertical and maximum tangential stresses. It means that brine pressure on the pillar lateral surface contributed to the strengthening of the edge zone of the whole pillars, since horizontal stresses in the pillars became compressive ones under the effect of brine. The concentration coefficients of vertical stresses were reduced by about 5% (Cherevko, 2006).

Thus, for the conditions of the Shevchenko mine, the uniform decrease in the pillars width is compensated by the pressure of the saturated brine on their walls in a certain approximation.

It makes it possible to evaluate the bearing capacity of the flooded mine structure without taking into account the changes in the parameters during theflooding process and the pressure of the brine.

2. The bearing pillars of rock salt react the load being deformed. All of them have undergone different stress changes during mine history. It is known, many factors determines the ultimate load on the rock salt pillars (and the ultimate deformation of pillars). One of the most important factor in determining the pillar stress for the same geological conditions is mine geometry, primarily, pillar sizes and mining parameter ratio (a width-to-height ratio for pillars and chambers). The Figure 4 shows the Shevchenko mine has various geometric parameters for different areas of the entire minefield. That is why the condition of the pillars at different areas significantly differs: by now,a part of the inter-chamber pillars and safety shelves is completely destroyed, but another part of the pillars are at different stages of the deformation processes. Some of the pillars have a fairly stable geomechanical state characterized by slow plastic deformations, while the other part is at the initial stage of ruptural deformations.

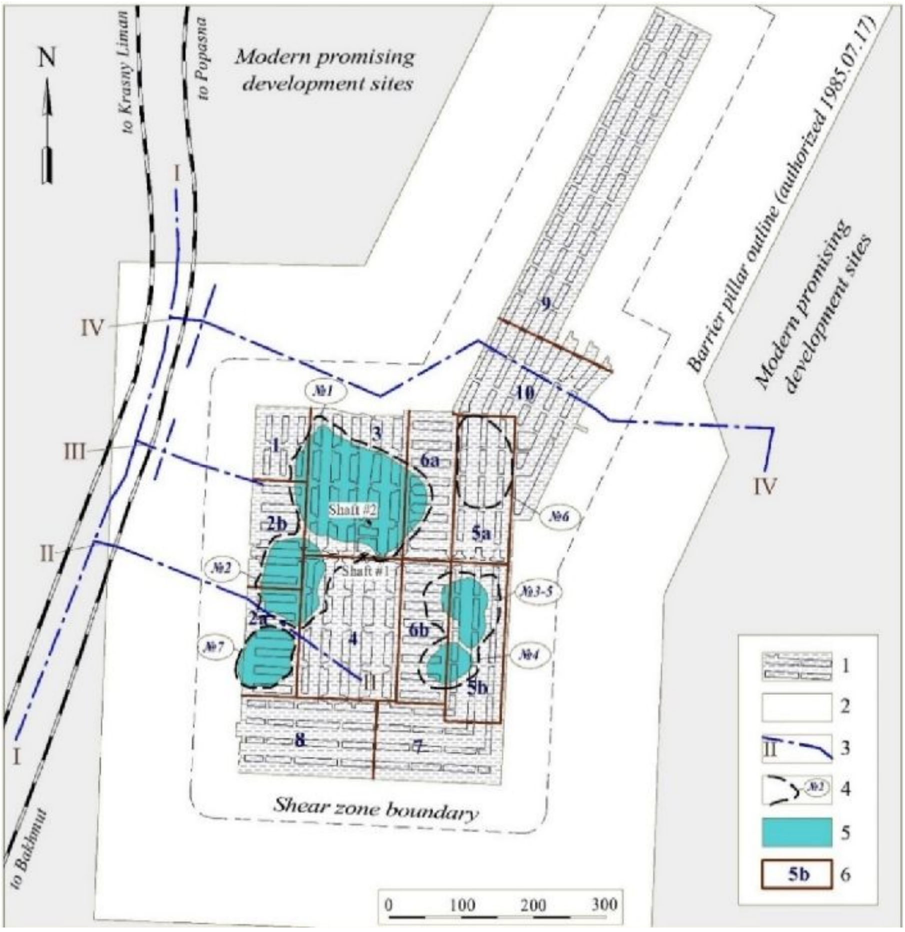

Fig. 4. Shevchenko salt mine layout and geometry integrated with the contours of the Earth's surface collapses
1 – flooded mine workings; 2 – barrier pillar around the mine field for the Bryantsevsky and lower-lying industrial layers approved in 17/07/1985; 3 – modern profile lines of instrumental monitoring of ground subsidence; 4 – the collapse pits on the Earth's surface (and their numbers showing the formation sequence); 5 – lake water surface created in the collapse craters; 6 – mine areas (panels) with different geomechanical characteristics (mining parameter ratio) and their numbers

Therefore, to understand the present deformation processes inside the created TGS and improve deformation forecasts, additional investigation has been performed for the condition assessment of the stability and lifetimes of the load bearing pil-lars all over the minefield. Modern methods of rock salt behavior assessing being applied for the Artyomovsk rock salt deposit (Metodicheskie, 1997) has been used.

It is understood that the lifetimes of the bearing pillars are the period of their plastic deformations without mechanical destruction (without pillar failure). The effect of the time factor has been estimated by using the factor of safety of the bearing capacity of the pillars (or the safety factor). The safety factor is determined by many criteria. The most important of which are the geometry of the mine workings (parameters of the rooms and pillars) and their depth since these criteria deter-mine the strain tensors and the initial point of destruction of the massif in time.

Forecasted lifetimes of constructive elements of development system for Artyomovsk rock salt deposit (t_p) are calculated on the basis of the equation of the rock salt state, using the theory of continuity Voltaire – Rabotnov (Metodicheskie, 1997):

$$t_p = 0{,}317 \cdot 10^{-7} \cdot \left[\frac{(n-1)\cdot(1-\alpha)}{\delta}\right]^{\frac{1}{1-\alpha}}, \qquad (1)$$

where α and δ – rheological parameters of rock salt determined empirically for rock salt of the BB in the lab of the USRI; n – safety factor calculated for real mining and geological conditions with an allowance for room parameters,the full overburden weight, strength and rheological characteristics of the BB rock salt.

Since the minefield consists of several panels with different characteristics, it was divided into sections of similar conditions for performing calculations (see Fig. 4). Within each section, the pillars are of the same height, the rooms are of the same width, and the roof depth differs by no more than 5%.

The pillar safety factors have been calculated for every sites using specially created computer program:

$$n = \frac{\sum_j S_j \cdot \sigma_{cj}}{H \cdot S \cdot \gamma}, \qquad (2)$$

where S – the area of the horizontal intersection of rock mass supported by supporting pillars, m^2; S_j – the bearing area of the horizontal section of the pillars (without correction for the decrease due to leaching), m^2; H – room depth = the thickness of the rocks from the Earth's surface to the roof of workings, m; γ– bulk density of rocks, which are supported by the pillars, N/m^3; σ_{cj} – the strength of rock salt pillar taking into account the ratio of its geometrical dimensions, Pa:

$$\sigma_{cj} = \sigma_c \cdot K_1 \cdot K_2, \qquad (3)$$

where σ_c – average limit compressive strength of rock salt of the BB, Pa (the value obtained for dry salt is used, since the softening factor of the rock salt is equal to 1 – research data for rock salt of the BB, VNIIG, Yu.P. Shokin, 1964; Asanov, 2010); K_1,$\cdot K_2$ – the coefficient of a pillar shape with a supporting area S_j: K_1– load coefficient (K_1 = 0.8 provided that the selected area is surrounded by an untouched massif from? at least two sides and its smaller linear size is less than the mine workings depth; K_l = 1 in the remaining cases); K_2 – coefficient expressing the dependence of rock salt compressive strength from? the ratio of the geometric parameters of pillars; for riband pillars of the Artyomovsk deposit (length-to-width ratio *>10)* this coefficient is a constant equal to 1.2.

The predicted pillars lifetimes corresponding to the beginning of the ruptural deformations and mechanical destruction of the pillars of each selected site were determined by formula (1), taking into account the calculated safety factors by formulas 2 and 3 (Table 1). As shown above, the first destructions of the pillars and the Earth's surface above them immediately after the beginning of flooding were associated with the development of man-made karst that "undercut" the pillars and sharply reduced their bearing capacity. These destructions lasted for not less than 20 years with fading speed. The pillars undisturbed by karst continued to deform at different rates, due to the mining and technical conditions of each site.

Table 1. Calculated normal safety factors and support pillars lifetimes within the Shevchenko minefield (the sites where the lifetime of rock salt pillars was completed are picked out with grey background)

Mine's panel number (see Fig. 4)	Depth of mine workings, m	Calculated safety factors	Calculated pillars' lifetimes, years	Period of site development (according to available archival data), years	The time when the pillars' lifetimes is completely used, years	Date of destruction of the earth's surface above the site
1	132.5	2.45	90	unknown, ≈ before 1910	≈ 2000	≈ 1950s*
2a	131.0	2.45	90	1910 – 1917	2000 – 2007	≈ 1960s*and **2012****
2b	131.0	2.45	90	unknown, ≈ before 1910	≈ 2000	≈ 1950s – 1970s*
3	120.0	2.90	260	unknown, ≈ 1892 – 1904	≈ 2152 – 2164	1942*
4	125.0	2.60	130	about 1892 – 1909	≈ 2022 – 2039	–
5a	145.0	2.36	70	unknown, ≈ 1917 – 1926	≈ 1987 – 1996	**1995****
5b	145.0	2.33	65	about 1926 – 1928	≈ 1991 – 1993	1946*
6a	140.0	2.50	100	unknown, ≈ before 1908	≈ 2008	1950*
6b	140.0	2.44	85	about 1892 – 1909	≈ 1977 – 1994	1946*
7	140.0	2.43	85	about 1929 – 1930	≈ 2014 – 2015	**2014****
8	130.0	2.66	145	about 1931 – 1933	≈ 2076 – 2078	–
9	167.0	2.94	260	about 1938 – 1940	≈ 2198 – 2200	–
10	160.0	2.63	130	about 1936 – 1941	≈ 2066 – 2071	–

* sinkholes created due to the technogenic karst undercutting pillars by leaching)

** collapse pits, which have been creating due to the pillars' lifetimes is completely used

As it can be seen in Table 1, by the beginning of 2000s the pillars' lifetimes within the most part of the minefield were already completely used or near completion. In this regard, a new series of destruction of the pillars and the formation of surface collapses began according to the geomechanical criterion. The destruction mechanism of the pillars and the all over-salt strata is described in detail in a number of works (Khrushchov et al, 2010; Asanov, 2010; Khrushchov and Bosevska, 2014). The main factor of destruction is the excess of rock pressure over the bearing capacity of the rock massif. Destroyed rocks (rock salt and non-salt rocks overlying the BB) filled the conforming mine rooms. In the next few years, the destruction of the pillars within the site # 7 will be completed, in a few more years the destruction of the central part of the minefield (site # 4), where the formation of a very large collapse is predicted, will begin. Sharp increase of Earth' surface subsidence rate over this mined-out area has already been determined by the results of instrumental monitoring of ground shifts (see below).

It should be underline that the calculated time for finishing of the pillar's lifetime (basic calculations were performed in 1990s) with great accuracy coincides with the time of large surface deformations (including the collapse formation). It is a clear confirmation of the correctness of the accepted methodological approach to ensure environmental safety during the Artyomovsk rock salt deposit development. From the standpoint of modern methodological approaches only support pillars with safety factor 3.0 and more meet the criterion of ensuring long-term stability (300 years and more) (Metodicheskie, 1997). From the standpoint of modern methodological approaches only load bearing pillars with safety factor 3.0 and more meet the criterion of ensuring long-term stability (300 years and more) (Metodicheskie, 1997). Modern mining areas are designed with safety factor 4.0 and more, despite the fact that in consequence it leads to decrease in the extraction ratio of rock salt.

The safety factors of the load-bearing capacity of the Shevchenko mine's pillars are predominantly less than 3.0 with the exception of two sites (# 3 и # 9). However the site # 3 was destroyed in early mine flooding (in 1942) due to leaching of the pillars bases near the mine shaft and the loss of their bearing capacity because of karst. Thereby, if the mine work-ings were not flooded and mine operation continued, this mine would be in an emergency condition due to the loss of pillar stability by the end of 1980s yet. In this case, the issue of measures developing to im-prove the pillars stability (e.g. by the method of backfilled of mined-out areas) or even mine abandonment (e.g. by method of man-made flooding)
would be up for debate.

3. The salt massif of the BB surrounding the minefield is not disturbed, stable and practically does not suffer changes. It has been confirmed by geophysical studies. Within the sections of the salt bed bordering the mined-out areas, the strain tensors are slightly modified, but it does not affect the stable time-dependent condition of the surrounding massif as a whole. The karst processes are also excluded because the leaching zone of the BB is removed to the east of the mine workings outline for a distance of 1.8 – 2.5 km. In connection with this, an increase in the minefield area is impossible.

The geological environment above the mine workings. In the undisturbed state, it was composed of easily deformable or brittle rocks, which are alternation of karst cavernous gypsum, cracked anhydrite, siltstone, argillite and clay. These rocks are not able to form stable "bridges" over voids, and therefore are prone to rapid destruction inherited from the destructed parts of the salt bed.

In this regard, the geological environment site in the impacted zone of the flooded mine is subject to complex technogenic disturbances, which are 1. Mechanical, 2. Hydrogeological, and 3. Geochemical (Khrushchov, et al, 2010).

1. 1. The mechanical disturbances include the following processes: large vertical shifts of rock slabs, crack growth, and crushing and grinding of the rock. Disruptive disturbances are activated cyclically and usually accompany the rock salt pillars collapse with a possible slight backlog in time (from several days to several months). The main acting factor for mechanical disturbances is the action of overburden pressure.

The long deformational processes occurring inside the rock mass are very uneven in area extent and over time. It is due to the difference in the bearing capacity of rock salt pillars. After failure of the bearing support, the accumulation of stress in the rock mass over the formed cavities occurs before the threshold limit of the geomechanical stability is reached, after which ruptural deformation of a corresponding block of the overlying rock mass begins.

To date, the entire massif of rocks over the minefield has been degraded; it has lost continuity and is divided into separate blocks with different varying geodynamic characteristics. Seismic exploration has showed that the largest disturbances in the massif are the system of deep subvertical cracks sep-arating large rock blocks. The mechanisms of deformation in each block differ somewhat depending on its position in the geological cross-section and deformation dynamics. With instant vertical movements such as natural vertical fault, some blocks still retain the primary layered structure. However, predomi-nantly every block are composed of shattered and redeployed rocks.

Deformations of the overlying rocks are greatly enhanced in connection with the ongoing general process of rock shifting (subsidence) as a result of plastic compression deformation of the remaining ("working") rock salt pillars. These deformations are also unevenly redistributed over the area due to different safety factors at different parts of the minefield ranging from 2.45 to 2.9 (see Table 1). Various deformation mechanisms of the overlying strata at the boundary of these blocks are superimposed with a cumulative effect.

Described condition of the overlying strata within the Shevchenko TGS is confirmed by all kinds of geophysical studies: gravitational and electric fields show instability, noticeable changes within the zones of increased cracking and indicate the continuing loss of continuity of rocks with different dynamic.

It should be mentioned in natural undisturbed conditions, there was gypsum karst in this area. We cannot deny the gypsum karst development now; however, it is obviously that changed local geological conditions do not promote gypsum karst processes, but slow down them. Therefore, the formation of large cavities associated with gypsum karst is practically excluded (Cooper, 1996; Cooper, 2002).

2. Hydrogeological disturbances in the overlying strata are secondary. They arose because of the disruption of the massif continuity as a result of which the entire strata of rocks inside the TGS were practically devoid of waterproof properties. The destroyed rock mass comprises a unified aquifer system. The active water exchange zone is above the mine workings by 40 – 50 m; it does not affect the flooded mine workings. The main stream of the groundwater is subhorizontal and directed to northwest toward the flood plain of the Bakhmut River (see Fig. 1). Its recharge is predominantly water of natural aquifers preserved outside the TGS. Hydraulic connection between the active water exchange zone and saturated salt water in the mine is one-way: the periodic upward flow of brines from the mine workings occurs because of extrusion by the subsiding rock strata and collapsed rocks. Reverse movement of aggressive water from the aquifer system toward the mine workings is impossible because of the lack of drainage conditions (Korotkevich, 1970). In case of huge collapses, saturated brines can rise up to the surface and drain into the lake basins (this process is described below).

3. Geochemical disturbances of the geological environment are associated with the periodic extrusion of saturated brines from the flooded mine workings. Ecological damage is minimal, since under-ground waters in the natural state are also mineralized because of salt and gypsum karst. In addition, as noted above, an aquifer support with highly mineralized brines of the leaching zone of the Above-Bryantsevsky bed takes place. The mineralization of the waters ranges from 156.3 to 310.0 g / l, so drainage of brines from TGS into adjacent aquifers westerly has practically no effect on the resulting chemical characteristics of natural aquifers. Nevertheless, by the results of calculation using the Dupuy formula the total removal of readily soluble salts from the TGS is about 220 tons / year.

Earth’s surface over the minefield. Before the flooding of the mine began, the relief of the Earth’s surface was flat, slightly hilly. The ongoing deformations of the rock mass are provoking a constant change in the geomorphological appearance of the over-mine area. Currently all surface deformations are associated with the uneven rock salt pillars’ deformations and the inherited collapse of the overlying strata. The surface shapes clearly reflect large deep deformations due to the geological features of the rocks (predominantly loose deposits). Only little localized deep collapses could occur without clear evidence at the surface. Therefore, monitoring of the surface condition permits controlling of the deep processes with a high degree of accuracy.

The surface condition monitoring includes a geomorphological monitoring and an instrumental subsidence monitoring, which were being performed for more than 50 years. The results of such a monitoring adequately characterize the development of surface deformations in terms of area, their spatial-temporal patterns, dynamics and the deformation style (Desir, 2018).

Geomorphological monitoring allows us to track the ongoing progressive degradation of the surface within the area, which is the projection of the mine workings on the surface. At the present time, the Earth’s surface is intensely dissected; by 2018, there are seven major collapse pits and several pronounced depressions. The approximate dimensions of the largest collapse in the area of the shafts (# 1, see Fig. 3) are 115 m × 175 m. The main geomorphological forms of relief clearly reflecting deeper deformations are as follows: saucer-shaped depressions of the surface, subsidence narrow gullies, large fracture cracks, finally, collapse pits with abrupt sides (Fig. 5). The lithological composition of Quaternary sediments (mainly red clays and loams) also predetermined the formation of second-order geo-morphological elements. Their formation is associ-ated with natural processes of levelling the primarily abrupt sides of collapses. These processes continue until reaching the repose angle and are manifested in the formation of temporary small geomorphological elements (landslides and breakaway cracks) and proesses (rock shedding, gravity displacement of the remnants) on steep slopes of the collapse craters.

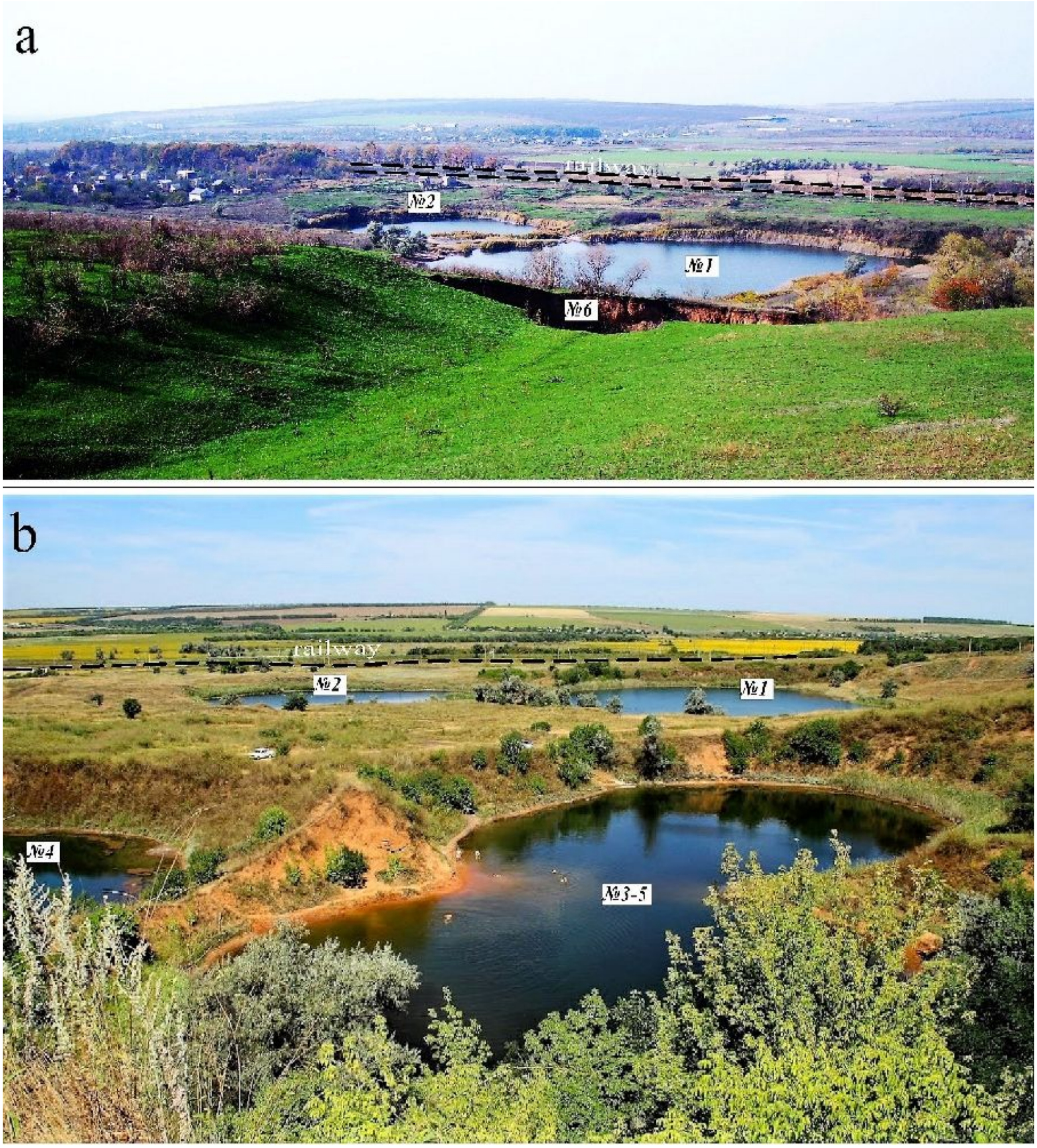

Fig. 5. Modern geomorphological display of the Shevchenko mine TGS: a – the Northeast view; b – the Southeast view

In the first stage of disruptive disturbances of the surface, as a result of karst processes (the first 20 years after the beginning of flooding), numerous little sinkholes were formed, which subsequently mer-ged into larger collapse pits.

In subsequent years, the geomechanical factor of new surface disturbance was dominant. In this case, collapse pits are formed usually as a result of a sudden (one-stage) collapse of entire overlying strata. The primary depth of the collapses is proportional with the height of the mine workings – up to 30 m, the primary diameter of the collapses are 50 m and more, the shape is usually round or elliptical. If new large collapses are formed next to the existing, their depths can be less (12 – 15 m), and duration of their formation can be bigger, up to a few years. It is due to the fact that the mine workings in these sites were already partially filled with previously collapsed rocks during the formation of adjacent collapses. Figure 6 shows the sequence of formation of a great collapse next to the old sinkholes.

Fig. 6. The developing of the newest collapse 7# as at: a – December 2012, b – May 2013, c – October 2013, d – September 2014, e – October 2016, f – November 2017

The instrumental monitoring of the Earth's surface subsidence extends beyond the boundaries of the TGS to define the boundaries of the mine influence zone and covers important objects of the infrastructure (e.g. the railway). Modern survey lines of subsidence control are shown in Figure 4. The results of instrumental control show the following:

- the general subsidence trough that covers the entire minefield develops continuously, but unevenly;
- local second and third order troughs are developing within the boundaries of the general subsidence trough;
- deformations of the Earth's surface are localized within the area that is the projection of mine workings on the surface;
- quantitatively, the surface subsidence rate is estimated from 2 to 6 mm/year to 400 mm/year.

Minimum stable subsidence usually takes place over mining sites that are in the steady creep stage and have a very large pillars' lifetime reserve (calculated sites # 9 and # 10, leveling line IV – IV). Maximum subsidence is usually fixed in period of the initial stage of the pillars destruction; they are a harbinger of the formation of conditions for the surface collapse (see Table 1 & Fig. 4).

At present, dynamic deformation processes develop over the calculated sites # 7, # 2a and # 4 where the pillars' lifetimes was completely used. The approximate pillars' lifetime of the site # 7 (southeastern part of the minefield) had expired in 2015. Since 2014, geomorphological monitoring has recorded the formation of large surface discontinuities in the form of a network of parallel cracks of varying degrees of expansion. Cracks are oriented along the long axis of the mine rooms. The development of cracks are still progressive. The largest cracks-ruptures reach a length of 200 m and are outlined by ravines.

The deformations of the surface within sites # 2a and # 4 are monitored by instrumental subsidence monitoring along the leveling line II – II. The calculated pillars' lifetime at the site # 2a was completed in 2007. Sharp increase in the dynamics of surface subsidence over this site with the formation of a local trough was recorded in the mid-1990s, when the subsidence increased to 35 – 55 mm/year. Further formation of the shift trough was accompanied by an increase in the subsidence rate in its central part (leveling marks # 197 – # 201) to 400 – 500 mm/year (2011 – 2012). In 2012, a collapse crater with a diameter of 15 m and a depth of 13 m occurred (collapse # 7, see Fig. 3), after which the subsidence of the adjacent area began to decrease gradually that corresponds to the stage of compacttion of the collapsed rocks.

Five years after the formation of the collapse, there was a decrease in the subsidence rate in the adjacent area within the calculated site # 2a by more than 40% of the maximum. Now the collapse is in

the stage of intensive development – secondary geo-morphological processes are superimposed on primary ones. Its dimensions reached a diameter of 80 m and a salt lake formed in the collapse crater (Fig. 7).

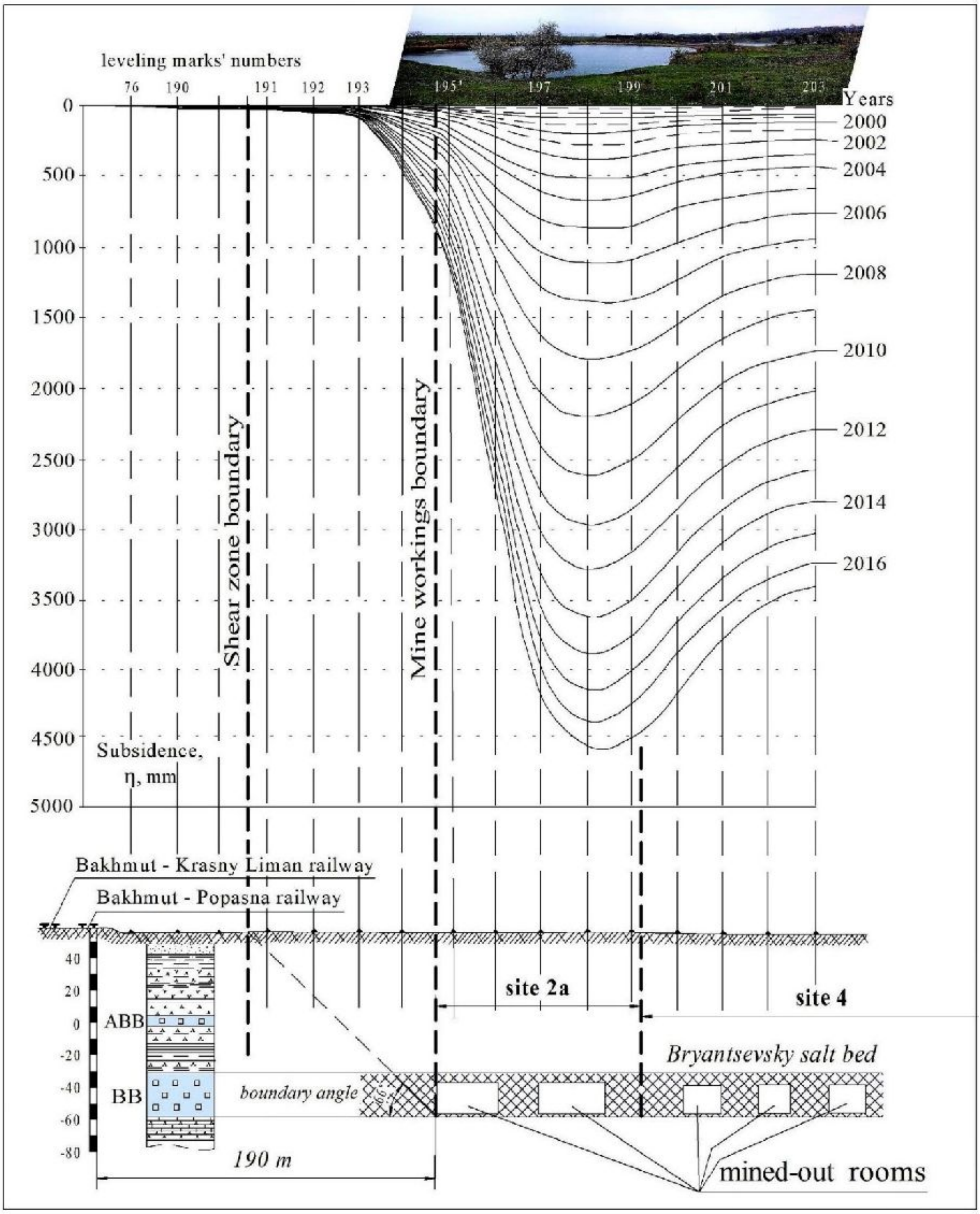

Fig. 7. The graph of Earth's subsidence within the Shevchenko mine TGS taken along line II – II (see Fig. 4)

Deep deformation processes in the central part of the minefield (calculated site # 4) are reflected in the surface subsidence up to 250 mm/year that shows the very large strains plastic deformations of the bearing pillars take place (tertiary creep – Phase III). The pillars' lifetime will be completely used in a few years.

Thereby, monitoring of surface deformations makes it possible to control deep deformation processes with high accuracy and confirms the correctness of modern methods of deformation control dur-ing deposit development.

Surface salt lakes were created in 6 basins of large collapse craters (see Fig.3 and Fig. 5). The bed of lake basins is composed mainly of heavy loams and red-colored clays (Q) with very low filtration properties. These rocks arepractically impervious.

The water-salt balance of the lakes is quite simple:a water-budget input is the brine pressed from the mine workings and the underlying brine aquifer complex, and the atmospheric precipitation falling on the lake area and on the limited catchment areas;a water-budget output is the water evaporation and negligible drainage during certain periods when conditions are created for it. The piezometric levels of the TGS aquiferous complex are generally below the bottom of the lakes, so their unloading into the lake basins is possible only when abrupt rise levels during the large shifts of rock blocks with the formation of new collapses or the rapid development of subsidence on the threshold of new collapses. The depth of the lakes is from seven to 14 m (from the water surface to the bottom). The lake basins are involved in the general process of lowering the Earth's surface.

In the water-salt regime in all lakes there is a cyclicity corresponding to the cyclic development of deformation processes in the rock mass and the stages of stabilization of the regime and its activation alternate. The stable regime stage of the lakes are characterized with the differentiation of water by mineralization in the absence of ascending flows and accumulation of fine clay particles clogging at the bottom of the lake. The lake basins become quasi-inland, and the lower parts of the lakes turn into a quasi-closed system with a stagnant water-salt regime.

In addition, biota colonies intensively develops in lakes during a periods of long-term stabilization of their regime. These are predominantly moderately halophilic bacteria (such as *Paracoccus*, *Vibrion*, othes), which, in order to ensure their vital activity, release a large amount of heat, raising the water temperature in the habitat of their colony. This significantly affects the distribution of the temperature gradient in depth and ensures the formation of a special bio-physical-chemical environment of the stagnant salt lakes (Andrashko and Sharkany, 2002). In this environment, in the absence of oxygen and the presence of hydrogen sulphide the transformation of a finely dispersed clay fraction into a typical black ooze or salt lakes (FeS) occurs, as well as the formation of colloidal solutions, which are complex disperse systems also takes place. The main components of colloids are the true sodium chloride brine, a highly dispersed clay substance, bacteria and microorganisms, as well as residues of their vital functions. All these processes enhance the bottom clogging which ensures a full waterproofing of the lower part of the lake basin.

Active stages are associated with activation of the rock subsidence processes and subsequent large movements of the slabs, up to the formation of new collapses. During this period, the aquiferous complex is not able to assimilate large portions of mine brines, which come at burst extrusion. As a consequence, squeezing brines into the lake basins through the formed waterways occurs. The salt composition of the incoming brines is dominated by NaCl, which increases the amount of calcium and sulfate ions. The active cycle of the lake regime sharply disturbs the formed bio-physical-chemical environment of the lake. It is characterized by a sharp increase in the mineralization of water (up to 100 – 150 g/l in the bottom layer) and the emergence of brineflows and airflows (squeezed out of air cushions in mine workings) leads to mixing of water layers and temporary equalization of mineralization and water temperature in depth.

Thus, the lake water-salt regime stages clearly reflect the dynamics of development of deformation processes inside TGS already at the initial stages of their activation. Therefore, hydrological monitoring provides significant additional information on the dynamics of development of deep processes. Hydrological monitoring has been carried out continuously, since the 1980s, and includes observations of changes in the hydrochemical and hydrodynamic characteristics of waters in the collapse lakes throughout the depth.

Since the development cycles of all lakes do not coincide in time and the hydraulic connection between the lakes is difficult or absent, the hydrodynamic and hydrochemical regime of all lakes is different. Namely, the level positions in nearby lakes differ by the same moment by 50 cm or more, the ranges of the mineralization variation with depth are different. The lake bio-physical-chemical environment depending on the amount of biota in different lakes and the local conditions for the development of colonies also differs (Table 2).

Table 2. The main indicators of the chemistry and temperature regime of waters in saline lakes formed over a flooded mine in 2017

Lake number	Sampling depth	April				October			
		Water temperature, °C	$CaSO_4$, g/l	NaCl, g/l	total soluble salts, g/l	Water temperature, °C	$CaSO_4$, g/l	NaCl, g/l	total soluble salts, g/l
1#	Surface layer	11,5	2,22	**10,49**	14,04	15,5	2,82	12,84	**17,49**
	Near-bottom water layer; 8,0 m	10,5	2,61	**14,77**	18,97	17,5	3,68	81,37	**89,56**
2#	Surface layer	11,5	1,97	**9,80**	13,28	15,5	3,14	12,25	**17,40**
	Near-bottom water layer; 12,0 m	12,0	3,78	**35,14**	43,41	18,5	3,82	42,72	**51,12**
3 – 5#	Surface layer	12,0	2,37	**20,09**	23,90	15,0	4,21	32,48	**38,73**
	Near-bottom water layer; 6,0 m	15,5	2,90	**37,76**	43,59	16,0	3,85	34,27	**40,51**
4#	Surface layer	12,0	1,51	**12,25**	15,26	15,0	2,39	17,65	**22,30**
	Near-bottom water layer; 9,0 m	11,0	2,29	**18,40**	23,21	15,5	2,38	18,38	**23,32**
7#	Surface layer	12,0	1,33	**7,35**	11,97	15,5	1,96	10,56	**14,24**
	Near-bottom water layer; 12,0 m	12,0	5,43	**82,51**	90,67	17,5	4,07	54,24	**60,71**

Nevertheless, for regimes of all lakes, the general patterns are noted: the same seasonal fluctuations in water levels, the increase in mineralization with depth and in the seasonal cycle from spring to autumn, the direction of the temperature gradient is increasing towards the top direction during warm season and increasing towards bottom during clod season.

At different stages of lakes development, the mineralization of waters on the lakesurfaces vary between 0.4 and 120 g/l, and at a depth of 7.0 – 144 g/l. During the entire monitoring period, the highest mineralization was recorded in the bottom layers of lake # 3 (160 g/l). At the same time, the highest water temperature at the bottom was + 29^{o}C, while the surface water temperature was 17^{o}C (long-term stabilization period). In each time, the highest mineralization is characteristic of lakes located within an actively deformable area. For example, as of 2017, the highest salinity of the bottom layer was recorded in lake # 7, which formed at the end (2012), the rock mass site under the lake basin remains in the stage of slow progressive deformations (see Table 2, fig. 6).

It occurs owing to the rise in level during the high water period and the possible emergence of conditions for drainage through non-clogging sides of the collapse (contain thin sand interlayers), the increasing dilution with fresh atmospheric water during expansion of the collapse pit due and the discharge of low-yield aquifers in some areas (e.g. the eastern side of the collapse # 3, where a fresh water source is periodically formed). The average seasonal fluctuations in the water level in the salt lakes are 0.35 m with a range of variations from 0.20 to 0.55 m.

Accordingly, despite the spatial proximity of all lakes there is a difference in the bio-physical-chemical environment in each of the salt lake. Any changes in this environment are also a “litmus test” for predicting deformational processes at depth.

Conclusion. Within the territory of the abandoned flooded Shevchenko salt mine, the labile quasi-closed technogenic geological system (TGS) has been formed in which long-term, multi-active destructive processes are occurring. The TGS is limited in area by a nominal enclosed vertical surface, the projection of which coincides with the shear zone boundary. At the bottom the TGS is limited by the base of the spent Bryantsevsky bed.

The driving force of TGS development is the processes of salt massif degradation up to mechanical destruction of the rock salt pillars within the minefield, provoked by hydrogeological and geomechanical factors in series.

All internal elements of the system have a stable one-way connection directed from the bottom up to the earth’s surface. The deformation processes are localized within the created system. They do not practically influence the geo-ecological situation beyond its borders. The binding of TGS and the surrounding rock mass is only carried out through the aquifers in the middle part of the geological section. Some removal of salts from the system is assimilated by the natural brine aquifer of the leaching zone of the overlying Above-Bryantsevsky salt bed, which adjoins it from the west closely.

The result of the formation and development of the system is a long destabilization of the relief of the Earth’s surface and the formation of unique lakes in the water-salt regime. The active processes of discontinuous deformations and surface collapses will continue unevenly for several tens of years.The deformation processes is expected to complete within a time period of 200 years or more. During this period of 200 years the first 50 – 60 years of them are an active period of collapse development in the main isometric part of the minefield. In this period, the geological environment and the Earth’s surface within the TGS completely looses their utility for any purposes however the likelihood of creating a threat to the nearby railway section is negligible.

On the one hand, the described deformation processes are typical for the flooded salt mines areas where the supporting rock salt pillars lost their stability. On the other hand, a combination of mining and geological factors has led to the creation of rather unique conditions, when all the negative effects have been localized within the system; while on the surface the salt lakes with a unique bio-physical-chemical environment have been formed. The unusual regime of the lakes with unexpected temperature changes and variable mineralization with the presence of colloids are of great media interest.

The performed assessment of the dynamics of the system development in time confirms the cor-rectness of the taken methodical approach to control mechanical behavior of salt during the Artyomovsk rock salt deposit development. In addition, the results of the investigations can be used to improve the methodology of salt mining in terms of decreasing of environmental risks in the densely populated areas overall as well as to develop of alternate improved safe room-and-pillar mining geometries that provide higher salt extraction while maintaining an appropriate safety factor for this and other rock salt deposits.

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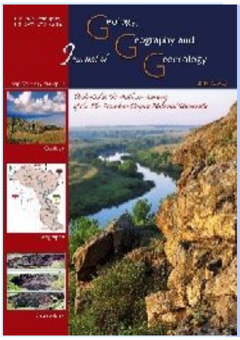

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Ecotoxicological status and prognosis of the state of an urbanized hydroecosystem (on the example of the reservoir "Ternopil pond")

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Abstract. As a result of a complex hydroecological research on the reservoir “Ternopil Pond”and comparison of these data with environmental and quality water standards we assessed the environmental threat posed by the content of certain substances, and the ecotoxicological state of the pond in general. A high concentration of HCO_3- was found, but the critical factor of water pollution is the significant concentration of ammonia, as well as the excess over the permissible levels of sodium ions. Moreover, we found polymetallic contamination of the bottom sediments with a high ratio of biologically dangerous mobile forms, with the exception of iron, and the excess over permissible levels (MPS), which in some places was ten times higher than the norm. The high level of the content of mobile metals forms was found at sampling areaswith a considerable sedimentation.The content of the mobile form of copper exceeded the norm by 24-86 times, nickel - from 2 to 17 times, cobalt – 4-8 times. The content of the mobile form of cadmium exceeded the permissible norm by 5-80 times, and lead – by 4.5-12 times. It was established that the content of the metals of the essential group in the water of the reservoir wasbelow the permissible values, and in the places where active flushing waters are flowing high concentrations of copper wasfound. Among the nonessential metals, cadmium and lead were found with fairlyhigh cadmium content , which is biologically dangerous because of the toxicity of this metal. In case of changes in the hydrochemical balance, the mobility of metals may increase, which will substantially worsen the almost disastrous pollution of the reservoir with highly toxic and biologically hazardous metals.Economic-mathematical modeling and statistical methods based on correlation-regression analysis using Matlab software were used to investigate the influence of ammonium content on the water pH index. The correlation index is ststistically significant and amounts to 0.86. This research will allow us to predict pH index of the water depending on the content of ammonium. The calculated elasticity coefficient shows that with an increase in ammonia by 10%, the pH index of the water will vary by 8%. In order to study the environmental situation in the near future, namely the content of metals in the bottom sediments, a forecast of the content of such metals as magnesium and cobaltfor the next two seasonal periods according to the theory of Markov chains has been made. This theory allows us to make predictions of the factor, taking into account the possibility of random effects on the environment, and investigates the greatest probability of presence of a factor in a certain numerical parameter.

Key words: water, bottom sediments, elasticity coefficient, correlation-regression analysis.

Екотоксикологічний статус і прогнозування стану урбанізованої гідроекосистеми (на прикладі водосховища "Тернопільський став")

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Анотація. У результаті комплексного гідроекологічного дослідження водосховища «Тернопільський став» шляхом порівняння отриманих показників з екологічними нормативами та стандартами якості навколишнього середовища оцінено екологічну небезпеку вмісту окремих речовин та екотоксикологічну ситуацію в цілому. Виявлено високі концентрації HCO_3^- і, критичним фактором у водоймі є накопичення аміаку у значних концентраціях, а також значне перевищення допустимих рівнів для йонів натрію, встановлено поліметалічне забруднення мулу з високою і біологічно небезпечною, крім заліза, часткою рухомих форм металів та переважанням допустимих рівнів у окремих місцях у десятки разів проти норми, відмічено високий рівень вмісту рухомих форм металів, які встановлено у точках з значним замуленням. Інструментарієм економіко-математичного моделювання та статистичних методів на основі кореляційно-регресійного аналізу з використанням сучасних інформаційних систем типу Matlab досліджено міру впливу вмісту амонію на кислотність води – показник кореляції є досить вагомий та становить 0,86. Проведене дослідження дозволить прогнозувати кислотність води через вміст амонію. Розрахований коефіцієнт еластичності свідчить, що при збільшенні амонію на 10% значення pH води буде змінюватись на 8%. Для дослідження екологічної ситуації на найближчу перспективу, а саме вмісту металів у донних відкладах, здійснено прогноз ситуації по вмісту металів на найближчі два сезонні періоди згідно теорії ланцюгів Маркова. Дана теорія дозволяє здійснювати прогнози чинника, враховуючи можливість випадкових впливів на середовище, та досліджується найбільша ймовірність перебування чинника в певному числовому параметрі.

Ключові слова: вода, донні відклади, коефіцієнт еластичності, кореляційно-регресійний аналіз.

Introduction. The attention paid both to the study and solving of environmental problems of fresh water ecosystems of inland water bodies is increasing due to the constantly increasing pollution (Romanenko etal., 2008; Shannon etal., 2011). Water quality is a limiting factor for water use in the face of a sharp increase in demand for fresh water (MyslyvaandKot, 2011). In recent decades, particularly dangerous for deterioration of the quality of natural waters are heavy metals (HM), which are considered to be the most dangerous for biota due to their toxicity and the ability to accumulate in hydrobionts (Nasrabadi, 2015; Perales etal. 2006). They belong to a class of conservative pollutants which do not decompose in the migration of trophic chains, they have mutagenic and toxic effects, greatly reduce the rate of flow of biochemical processes in aquatic organisms (Maliket al., 2014; Abubakar et al., 2015; Rashed 2001). Some of them are toxic even at very low concentrations (Myslyvaand Kot I., 2011), and such important elements as Fe, Cu and Zn, at elevated concentrations can also be biologically dangerous (Manoj etal., 2012).

First of all, the research related to the study of hydrochemical levels of pollution is relevant and, consequently, it is important to analyse their impact on the reactivity and self-sustainability of hydrobionts groups that provide the productivity and ductility of hydro ecosystems, their resistance to pollution and self-purifying capacity. Such studies, on the one hand , allow one to predict the possible consequences of pollution, and on the other hand, to model and plan measures to restore the natural status of an ecosystem, which supports the quality of water and the recreational and resource potential of reservoirs (Romanenko et al, 2015,Nesaratnam and Suresh, 2014, Correl, D.L. 1998). In order to predict and elaborate proposals for restoration measures in regulated freshwater ecosystems, we examined hydrochemical, toxicological and hydrobiological parameters that reflect the level of contamination, quantitative and qualitative characteristics of the development of aquatic organisms, as well as the effect of toxic factors on the water ecosystem of the reservoir Ternopil Pond (Romanenko, 2015; Grubinko et al.,2013).

The use of modeling tools and statistical analysis when studying the ecotoxicological situation of hydrosystems is relevant in modern conditions. The abovementioned problems are studied by modern scholars (Akin et al,2011; Budka et al, 2013). It is necessary to study the question of sources and ways of contamination of hydroecosystems of ribbon type reservoirs in the conditions of loading of various environmental pollutants (heavy metals, etc.), violation of the hydrochemical and hydrobiological regime in ecosystems, the development of the process of “eutrophication” (flowering) in reservoirs, the quality of the water environment and water, ways of preserving and increasing biodiversity, ensuring the sustainability of the succession series (development) of reservoir ecosystems in order to increase their environmental sustainability, expanding capacities for recreational and economic use of water and biological resources in accordance with the requirements of the environmental norms of Ukraine and the EU Water Framework Directive 2000/60 (*Directive* …, 2000), maintaining on this basis a stable social and environmental situation of cities, restoration, protection and rational use of natural resources.The model of the ecotoxicological assessment and forecast of the ecosystem “Ternopil pond” can be considered as the basis for developing measures for preservation and optimization of recreational and water use of internal reservoirs of the lagoon water system of urbanized territories of Ukraine (Grubinko etal., 2013).In a view of the above, the purpose of our research is to determine the control variables (the content of heavy metals and some physical and chemical indicators of water) based on the analysis of the current state of the object, the implementation of which allows for the desired behaviour or state of the object of nature use.

Materials and methods. 1. Sites of research and their ecological characteristics. The natural water reservoir "Ternopil Pond" served as the object of study. Taking into account the pecularities of the hydroecological characteristics of this water body and factors of their formation, we selected monitoring sites described in Fig. 1.

Fig. 1. The scheme of monitoring sites of the reservoir "TernopilPond" (1: 15000).

Sampling sites:

1 –areaof the backwater and the discharge of flushing waters from Ruska Street: the nearest distance from the shore (dam) - ~ 25 m, depth of sampling - 2.6 m; characterized by the low intensity of water exchange, stagnant phenomena, inflow of coastal effluents, clogging up; bottom condensed, sandy-pebble with a significant number of shells of dead individuals and individual living molluscs (up to 10-12 cm depth); medium vegetation was detected;

2 – area of backwaternear the pier: the nearest distance from the riverbank is ~ 50 m, sampling depth - 6.8 m; characterized by the low intensity of water exchange, stagnant phenomena, inflow of coastal drainsfrom the hotel "Ternopil", clogging; the bottom with fallen leaves, sand-mullish (to a depth of 60 cm, there are no shells of dead individuals, live molluscs and vegetation);

3 – the area behind the island: the nearest distance from the bank is ~ 40 m, sampling depth is 4.7 m; a natural barrier to the migration of pollutants from oil trap and discharge of flushing water through the canal (Rudka river) from Krushelnytska Street and the beach "Tsyhanka"; bottom of loose, sandy-mullish (to a depth of more than 90 cm there are no shells of dead individuals, live molluscs and vegetation);

4 – area opposite the Khutir restaurant: the nearest distance from the bank is ~ 30 m, sampling depth is 2.0 m; is characterized by the flow of man-made emissions from the drainage and atmospheric precipitation from the territories of the "Dalnii Beach", the boats mooring and the Khutir restaurant, the bottom of medium-density**,** sandy-pebble (to a depth of about 50 cm, there are single shells of dead individuals and live molluscs and vegetation);

5 – area of the backwater and discharging flushingwater from the hotelHalychyna: the nearest distance from the bank is ~ 50 m, sampling depth is 5.0 m; characterized by the low intensity of water exchange, stagnant phenomena, inflow of coastal effluents, clogging up; bottom of loose, sandy-mullish (to a depth of more than 60 cm there are no shells of dead individuals and live molluscs, there is sparse/poor vegetation);

6 – admissible area: the nearest distance from the shore (dam) - ~ 30 m, depth of sampling - 2.4 m; near the main channel and the gateways, is characterized by high intensity of water exchange; bottom condensed, sandy-pebble with a significant number of shells of dead individuals and individual live molluscs (to a depth of 10-12 cm); medium vegetation was detected;

7 – area from the village of Bila: the nearest distance from the shore is ~ 30 m, sampling depth is 3.7 m; flushing from the village of Bila; bottom of loose, sandy-mullish (to a depth of about 60 cm there are no shells of dead individuals and live molluscs, sparse/poor vegetation);

8 – distant beach area: the nearest distance from the river bank is ~ 25 m, depth of sampling - 1.8 m; is characterized by the flow of flushed waters with runoff and atmospheric precipitation from the territories of the private sector of the village of Kutkivtsi and "Dalnii" beach, the bottom is medium-dense, sandy-mullish (to a depth of about 40 cm there are single shells of dead molluscs).

The selected areas take into account the main sources of pollution with flushing water and water collectors (sites 1, 3, 4, 7, 8) and the hydrological regularities of migration and accumulation of toxic substances and correlate with the places of eutrophicationin the reservoir that were observed in previous years. (Grubinko, etal. 2013., Gumenyuk, 2003).

Methods of hydrochemical research. All measuring instruments used in the research are standardized and endorsed with the expertise of the State Enterprise "Ternopil Scientific and Production Center of Standardization, Metrology and Certification" by the issue of certificates of verification of the regulated regulatory instrument of measuring equipment from 14.09.2016: atomic absorption spectrophotometer C 115 M (Certificate No. 743 -F); ionizer EV 74 (Certificate No. 745-F); spectrophotometer SF 46 (Certificate No. 742-F); Fluorocarbonometer KFK-2 (Certificate No. 744-F); Oxygenizer AHA-101,1 V1 (Certificate No. 741-F); liquid chromatograph "Crystal 200" (certificate number 266-F).

The number of samples at each site was repeated three times. The measurements are given as an arithmetic mean of three measurements at each sampling site.

The content of heavy metals in water and sediment was determined by atomic absorption spectrophotometry (Ermachenko, 1997).

Ammonium cations in water and sediment were determined colorimetrically (Romanenko, 2006). The method is based on the ability of ammonia and ammonium ions to form a yellowish brown colour of the compound with a Nessler reagent.

The determination of the concentration of nitrates was carried out by colorimetric method with phenol disulfonic acid (Romanenko, 2006). The method is based on the reaction between nitrates and phenol disulfonic acid to form nitro-derivative phenols, which form yellow compounds with alkali compounds.

Determination of nitrites was carried out colorimetrically (Romanenko, 2006). The methods are based on the formation of azure colour of red colour when passing the reaction of nitrite ions with the Grissa reagent.

The ecological danger of the content of certain substances and the ecotoxicological situation as a whole were assessed by comparing the indicators with environmental norms and environmental standards: toxicity on the basis of comparison of indicators with the values of MPC (Maximum permissible concentrations of harmful substances in water of water reservoirs of household and drinking and cultural and household purposes) (Rules…, 1999), and ecotoxicological danger in accordance with the "List of pollutants for determining the chemical status of the arrays of surface and ground water and ecological potential of anartificialor substantially modified surface water massif" (List …, 2017).

In order to study the effect of ammonium on water pH index, the statistical analysis methods, namely correlation-regression analysis (Akin B.S., 2011), are used, the correlation index is quite significant and is 0.86, the study will allow adjustment of the water pH index through the content of ammonium. The calculated elasticity coefficient shows that with an increase in ammonia by 10%, the water pH index will change by 8%. Also, the prediction of the content of heavy metals in the bottom sediments by the method of Markov chain theory is carried out. This theory allows us to make predictions of the factor, taking into account the possibility of random effects on the environment, and investigates the greatest probability of presence of a factor in a certain numerical parameter (Rogatunskiy R. and Garmatiy N.2015).

Results

pH Index of water (Table 1).

Table 1. pH index of water (M±m)

Indexes	range	Selection Sites							
		1	2	3	4	5	6	7	8
pH	1-14	8.02±0.05	7.31±0.03	7.40±0.04	7.52±0.03	7.39±0.02	7.52±0.03	7.24±0.05	7.46±0.02

At all the sites investigated, the water has a pH> 7, which contributes to the presence of carbon dioxide in the form of a hydrocarbonate ion, providing an environmentally acceptable gas regime of water and the absence of obsolescent phenomena. The increase of pH of watermay be the decay of organic sucstances in the bottom layer and the sludge with the formation of ammonia and the salinity of the reservoir with alkaline equivalents of flushing origin. High alkalinity of water also contributes to the transition of a significant amount of ammonia to highly toxic ammonia, which degrades the ecotoxicological situation of the reservoir, since ammonia is 200 times more toxic than ammonium (MAC NH_4 + = 2.0 mg / l; HDCNH_3 = 0.01 mg / l).

2. The content of nitrogen compounds (Table 2,3).

Table 2. The content of ammonia, nitrites and nitrates in water (M±m)

Forms of nitrogen	MPC, mg/l	Sampling sites							
		1	2	3	4	5	6	7	8
NH_4^+, mg/l	2.0	20.0±1.8	67.0±3.4	68.0±4.6	62.0±2.9	60.0±4.3	31.0±2.3	69.0±2.7	57.0±3.4
NO_2^-, mg/l	3.0	0.005± 0.0004	0.007± 0.0003	0.15± 0.001	0.06± 0.004	0.09± 0.008	0.01± 0.002	0.17± 0.03	0.12± 0.007
NO_3^-, mg/l	45.0	0.005± 0.0003	0.1± 0.006	0.05± 0.004	0.09± 0.003	0.14± 0.04	0.06± 0.003	0.08± 0.004	0.16± 0.008
NH_4^+: NO_2: NO_3^-, %	-	100: 0.025: 0.025	100: 0.01: 0.15	100: 0.22: 0.07	100: 0.10: 0.15	100: 0.15: 0.23	100: 0.03: 0.19	100: 0.25: 0.12	100: 0.21: 0.28

From the data obtained it is evident that in the water and in the sediments (sludge) there was an active ammonification resulting from the decomposition of organic matter that settled during the winter and was oxidized. The most polluted ammonia water is in the streams of flow from the village of Bila, stagnant water near the "Nadstavna Church", behind the island from the side of "Tsyhanka" beach, near the restaurant "Khutir" and near the boat station (exceeding the MPC by almost 30 times). Less contaminated due to leakage are areas near the dam (water drain - western and eastern - sites 6 and 1) (exceeding the MPC by 10-15 times).

The most polluted ammonia sludge is on sites near the "Nadstavna Church", from the side of the runoff from the village of Bila and behind the island from the side of "Tsyganka" beach (exceeding the MPC by almost 100-150 times).

Data on the content of ammonium, nitrite and nitrate in the bottom sediments are presented in Table 3.

Table 3. The content of ammonium nitrites and nitrates in the bottom sediments (M±m)

Forms of nitrogen	Sampling sites							
	1	2	3	4	5	6	7	8
NH_4^+, mg /100g. over dry ground	95.5±5.3	219.0±4.7	325.1±8.9	85.4±7.3	120.5±6.7	116.8±4.3	265.2±9.1	162.4±5.2
NO_2^-, mgr/100 g over dry ground	5.5±0.3	1.7±0.2	1.6±0.1	1.5±0.2	1.5±0.3	2.1±0.2	2.3±0.4	1.7±0.2
NO_3^-, mg/100 g over dry ground	0.1±0.009	3.0±0.09	0.7±0.03	1.2±0.07	1.1±0.01	0.8±0.03	1.2±0.05	0.9±0.02
NH_4^+: NO_2^-: NO_3^-, %	100: 5.3: 0.1	100: 0.8: 1.4	100: 0.5: 0.2	100: 1.8: 1.4	100: 1.3: 0.9	100: 1.8: 0.7	100: 0.9: 0.5	100: 1.0: 0.6

Exceeding norms of nitrites and nitrates was not revealed - the levels in the water were much lower than the maximum permissible standards.

Hence, one of the critical factors for aquatic organisms, especially the bottom layer and sludge, is the ammonation and accumulation of ammonia in significant concentrations and its presence in the form of highly toxic NH_3 due to the alkalinity of water.

Based on the correlation-regression dependence, we will investigate the effect of the ammonium content (Table 3) on the pH index of water (Table 2). The calculations are made in the software Matlab.

```
Y=[8.02; 7.31; 7.40; 7.52; 7.39; 7.52; 7.24; 7.46]
Y =
   8.0200
   7.3100
   7.4000
   7.5200
   7.3900
   7.5200
   7.2400
   7.4600
>> X1=[20; 67; 68; 62; 60; 31; 69; 57]
X1 =
   20
   67
   68
   62
   60
   31
   69
   57
>> corrcoef (X1,Y)
ans =
   1.0000   -0.8622
  -0.8622    1.0000
```

Correlation is strong and is 0,86

```
>> glmfit(X1,Y)
ans =
   8.0855
```

-0.0111

Regression equation y=8.0855-0.0111x

Coefficient of elasticity E=(-0.0111*57)/(8.0855+(-0.0111*57))

E = -0.0849

Also, the method of correlation-regression analysis investigated the effect of ammonium on the pH index of water, the effect is quite significant and is 86%. The coefficient of elasticity was calculated on the basis of this value. The coefficient of elasticity suggests that with an increase in ammonia
by 10%, the pH index of water will decrease by 8%.

3. The content of metals (Table 4, 5).

Traditionally, according to the degree of biological danger, metals are divided into three groups: biogenic (necessary for organisms in high concentrations), essential (necessary for life in microconcentrations, exceeding of which adds up to toxicity), and nonessential (toxic in any concentrations). On the other hand, biological activity is manifested only by the so-called mobile forms (soluble, ionic). Therefore, the gross metal content in living environments reflects their total pollution and the degree of accumulation, and the biological hazard reflects the level of mobile forms.

Table 4. The content of metals in water *(M±m)

Content of metals, mg/l	MPS*mg/l	Selection sites							
		1	2	3	4	5	6	7	8
Biogenic									
Sodium	200.0	239.0± 7.2	212.0± 11.7	223.5± 6.4	217.2± 5.9	214.3± 7.5	228.5± 6.0	231.7± 7.0	212.4± 9.3
Potassium	n.l	4.30± 0.41	4.55± 0.37	5.13± 0.49	4.85± 0.32	4.70± 0.44	5.40± 0.35	4.73± 0.41	4.45± 0.22
Calcium	n.l.	7.19± 0.67	6.35± 0.56	3.08± 0.36	0.40± 0.06	1.30± 0.04	0.57± 0.05	3.8± 0.12	1.2± 0.07
Magnesium	40.0	6.28± 0.47	25.88± 1.64	10.23± 0.17	8.29± 0.75	10.13± 1.13	6.65± 0.55	9.64± 0.19	7.68± 0.33
Essential (toxic in high concentrations)									
Iron	0.3	0.015± 0.001	0.005± 0.0007	0.004± 0.0001	0.001± 0.0005	0.002± 0.0001	0.005± 0.0002	0.004± 0.0002	0.002± 0.00009
Cobalt	0.1	0.002± 0.0002	0.002± 0.0001	0.002± 0.0001	0.002± 0.0001	0.002± 0.0001	0.002± 0.0001	0.002± 0.0001	0.002± 0.0001
Manganese	0.1	0.0002± 0.00001	0.0002± 0.00001	0.0002± 0.00001	0.0002± 0.00001	0.0002± 0.00001	0.0002± 0.00001	0.0002± 0.00001	0.0002± 0.00001
Copper	1.0	0.065± 0.003	0.008± 0.004	0.042± 0.006	0.023± 0.001	0.15± 0.001	0.20± 0.007	0.036± 0.003	0.009± 0.001
Nickel	0.1	0.0008± 0.00001	0.0008± 0.00006	0.0008± 0.00005	0.0008± 0.00003	0.0008± 0.00002	0.0008± 0.00001	0.0008± 0.00002	0.0008± 0.00003
Zinc	1.0	0.0005± 0.00002	0.0005± 0.00001	0.0005± 0.00003	0.0005± 0.00002	0.0005± 0.00001	0.0005± 0.00003	0.0005± 0.00001	0.0005± 0.00002
Non-essential (toxic)									
Cadmium	0.001	0.0005± 0.00001	0.0005± 0.00001	0.0005± 0.00002	0.0005± 0.00002	0.0005± 0.00001	0.0005± 0.00003	0.0005± 0.00001	0.0005± 0.00002
Lead	0.03	0.01± 0.001	0.01± 0.0007	0.01± 0.0007	0.01± 0.0005	0.01± 0.0006	0.01± 0.0005	0.01± 0.0005	0.01± 0.0005

Note: * - a mobileform; nl - not limited

In the water, excess over the maximum permissible levels was found only for sodium ions (Table 4), which, along with the sum of ions of other metals, indicates a significant salinity of the water of the pond, especially at the sites of active washings and drains from the coast: 1 and 6 - from the dam, 3 from side of Krushelnytska Street, 4 - from the restaurant "Khutir", 7 from the "Novyi Svit" neighborhood and the village of Bila. Taking into account the nature of communal activities, it is possible that the main source of salinity is the use on the roads and side- walks of bulk salts and slags in the winter.

The content of metals of the essential group in the water is much lower than the maximum permitted values, which may be the result of their deposition in silicate phosphates, which form the soluble salts with these met-als. However, copper is found in high concentrations inthe areas of active flow of flushing water.Among nones-sential metals, only cadmium and lead have been found. Moreover cadmium content, although not reaching the maximum permissible levels, is quite high and biologically dangerous because of the extremely high toxicity of this metal, which is still mutagenic.In the silt (see Table 5), extremely high indexes of metals content of all investigated groups were detected.

For the biogenic group of metals, low mobility (an exchange fund with water) is found to be 1-5%, and the vast majority of them, most likely, are recorded in colloids, humic complexes of silt and other organic substances.Among the metals of the essential group, the excess of the norm of gross content for copper was found to be 18-67 times, nickel - 1.5-10 times, cobalt - 1.5-3 times, a high level of mobile zinc was established. The high level of accumulation of metals is set at sites with significant sedimentation, phosphate content and high pH values - sites 2-5, the least precipitated metal compounds in the admixture - sites 1 and 6.At the same time, guided by the principle of high toxicity of the mobile metals, it is worth mentioning that the iron in the silt is is mainly connected, and therefore biologically safe. As for other metals, the degree of their mobility, and, consequently, the biological threat, we can make a row: copper> nickel> manganese> cobalt> zinc. Among the metals of the essential group, the excess of the norm of the content of the mobile mold for copper was detected - 24-86 times, nickel - from 2 to 17 times, cobalt - 4-8 times, high level of iron and zinc.

Table 5. The content of metals in the bottom sediments

Metal content mg / kg dry the sediment	MPS * mg / m^3	Sampling sites							
		1	2	3	4	5	6	7	8
Biogenic									
Sodium	nl	18760.1 215.6 (1.2%)	20465.3 230.5 (1.1%)	24830.1 315.3 (1.2%)	22680.5 306.9 (1.3%)	33180.2 389.1 (1.1%)	29040.5 430.9 (1.5%)	28300.2 339.6 (1.2%)	20860.3 271.8 (1.3%)
Potassium	nl	3909.1 187.5 (5%)	5076.2 250.9 (5%)	5863.2 292.8 (5%)	5847.3 292.7 (5%)	3546.5 271.8 (8%)	3847.1 271.9 (7%)	5984.2 359.0 (7%)	4487.4 224.3 (5%)
Calcium	nl	186600 5430 (3%)	188169 5215 (3%)	164720 5265 (3%)	89305 3375 (4%)	192800 5648 (3%)	199211 7790 (4%)	176204 7048 (4%)	99530 3982 (4%)
Magnesium	nl	25601.1 212.3 (0.8%)	94442.3 807.5 (0.8%)	105200.1 1020.1 (0.9%)	107404.3 1262.3 (1.2%)	126902.4 1200.1 (0.9%)	81010.2 634.9 (0.7%)	117364.3 1408.4 (1.2%)	115020.2 1380.2 (1.2%)
Essential (toxic in high concentrations)									
Iron	n.l.	6110.1 121.3 (2%)	22368.6 438.6 (2%)	35436.7 725.4 (2%)	45721.9 933.1 (2%)	35955.0 720.6 (2%)	21128.4 408.9 (2%)	43537.6 877.7 (2%)	32495.0 649.9 (2%)
Cobalt	5,0	19.4 8.7 (45%)	32.2 15.3 (48%)	33.4 15.0 (45%)	30.5 12.1 (40%)	30.4 12.9 (43%)	19.9 9.5 (47%)	29.4 13.2 (45%)	21.0 9.0 (43%)
Manganese	n.l.	424.8 227.5 (54%)	784.2 392.8 (50%)	699.4 550.4 (78%)	737.1 511.3 (69%)	811.8 489.1 (60%)	371.2 300.2 (81%)	645.4 503.4 (78%)	612.5 367.5 (60%)
Copper	3,0	72.1 54.2 (75%)	260.3 200.9 (77%)	236.8 174.5 (74%)	129.3 115.1 (89%)	154.4 93.3 (60%)	89.3 75.1 (84%)	206.1 152.4 (74%)	138.9 83.4 (60%)
Nickel	4,0	19.4 12.7 (65%)	52.7 31.2 (59%)	69.4 41.4 (60%)	58.4 42.4 (73%)	46.5 33.5 (72%)	9.9 6.1 (61%)	57.6 34.6 (60%)	43.2 31.1 (72%)
Zinc	n.l.	2282.4 850.1 (37%)	3536.4 1268.1 (36%)	3353.2 1198.4 (36%)	2515.2 1064.2 (42%)	2976.1 1235.1 (42%)	2192.3 1023.2 (47%)	3235.6 1164.8 (36%)	2467.1 1036.2 (42%)
Nonessential (toxic)									
Cadmium	0,01	0.074 0.05 (68%)	1.92 1.28 (67%)	0.25 0.15 (60%)	1.33 0.83 (62%)	0.087 0.05 (57%)	0.075 0.04 (53%)	0.35 0.21 (60%)	0.078 0.05 (57%)
Lead	6,0	31.1 27.0 (87%)	72.9 65.1 (89%)	78.1 71.9 (92%)	37.3 20.2 (54%)	65.4 57.2 (88%)	52.2 45.0 (86%)	72.3 66.5 (92%)	31.5 27.7 (88%)

Note: gross shape mobile form (% of the mobile from gross);
* - MPS applies only to the mobile form; nl - not limited

The high content of mobile forms of metal is revealed at sites with significant sedimentation, lower oxygen content and higher pH values - sites 3-5, the smallest in the close to dam area - sites 1, 6 and in the plant opposite the hotel "Terno-pil".Concerning nonessential metals, one can state that there is the pollution of silt of the pond with mobile cadmium (almost 60%) and lead (almost 90%). In this case, the content of mobile cadmium exceeds the permissible norm 5-80 times (at site 2 near the boat quay this norm was exceeded by 128 times), and lead - by 4.5-12.

According to the data presented in Table 5 on the content of metals in the bottom sediments, we make a forecast of the situation for the next two seasonal periods according to Markov chain theory. This theory allows one to make predictions of a factor, including the possibility of random effects on the environment, and investigates the greatest probability of presence of a factor in the most favourable state.Realization is carried out in software Matlab. Predicting the content of cobalt, copper, nickel and manganese in bottom sediments for the next 4 seasons, for possible monitoring of the situation.

Projected calculations of the content of cobalt in bottom sediments for two seasons for the near future.

```
>> A=[19.4, 32.2, 33.4, 30.5, 30.4, 19.9, 29.4, 21.0]
A =
  19.4000  32.2000  33.4000  30.5000  30.4000
19.9000  29.4000  21.0000
>> S=19.4+32.2+33.4+30.5+30.4+19.9+29.4+21.0
S =
  216.2000
>> C=[216.2000, 216.2000, 216.2000, 216.2000, 216.2000, 216.2000, 216.2000, 216.2000]
C =
  216.2000  216.2000  216.2000  216.2000
216.2000  216.2000  216.2000  216.2000
>> rdivide(A,C)
ans =
   0.0897  0.1489  0.1545  0.1411  0.1406
0.0920  0.1360  0.0971
>> B=[0.0897, 0.1489, 0.1545, 0.1411, 0.1406, 0.0920, 0.1360, 0.0971; 0.1489, 0.1545, 0.1411, 0.1406, 0.0920, 0.1360, 0.0971, 0.0897; 0.1545, 0.1411, 0.1406, 0.0920, 0.1360, 0.0971, 0.0897, 0.1489; 0.1411, 0.1406, 0.0920, 0.1360, 0.0971, 0.0897, 0.1489, 0.1545; 0.1406, 0.0920, 0.1360, 0.0971, 0.0897, 0.1489, 0.1545, 0.1411; 0.0920, 0.1360, 0.0971, 0.0897, 0.1489, 0.1545, 0.1411, 0.1406; 0.1360, 0.0971, 0.0897, 0.1489, 0.1545, 0.1411, 0.1406, 0.0920; 0.0971, 0.0897, 0.1489, 0.1545, 0.1411, 0.1406, 0.0920, 0.1360]
B =
   0.0897  0.1489  0.1545  0.1411  0.1406
0.0920  0.1360  0.0971
   0.1489  0.1545  0.1411  0.1406  0.0920
0.1360  0.0971  0.0897
   0.1545  0.1411  0.1406  0.0920  0.1360
0.0971  0.0897  0.1489
   0.1411  0.1406  0.0920  0.1360  0.0971
0.0897  0.1489  0.1545
   0.1406  0.0920  0.1360  0.0971  0.0897
0.1489  0.1545  0.1411
   0.0920  0.1360  0.0971  0.0897  0.1489
0.1545  0.1411  0.1406
   0.1360  0.0971  0.0897  0.1489  0.1545
0.1411  0.1406  0.0920
   0.0971  0.0897  0.1489  0.1545  0.1411
0.1406  0.0920  0.1360
>>  p=[0, 0, 1, 0, 0, 0, 0, 0]
p =
   0  0  1  0  0  0  0  0
>> p1=[p*B]
p1 =
   0.1545  0.1411  0.1406  0.0920  0.1360
0.0971  0.0897  0.1489
>> p2=[p1*B]
```

That is, the next season, the content of cobalt in the bottom sediment with the highest probability of 0.1545 will be 19.4

```
p2 =
   0.1243  0.1254  0.1302  0.1254  0.1243
0.1242  0.1220  0.1242
>> p3=[p2*B]
```

In 2020, the cobalt content in the bottom waters of the reservoir with the highest probability of 0.1302 will be 33.4 units. We will carry out a forecast of manganese content in the bottom sediment of the reservoir for the next two years.

```
>> A=[424.8, 784.2, 699.4, 737.1, 811.8, 371.2, 645.4, 612.5]
A =
  424.8000  784.2000  699.4000  737.1000
811.8000  371.2000  645.4000  612.5000
>>
S=[424.8+784.2+699.4+737.1+811.8+371.2+645.4+612.5]
S =
  5.0864e+03
>> C=[5.0864e+03, 5.0864e+03, 5.0864e+03, 5.0864e+03, 5.0864e+03, 5.0864e+03, 5.0864e+03, 5.0864e+03]
C =
  1.0e+03 *
   5.0864  5.0864  5.0864  5.0864  5.0864
5.0864  5.0864  5.0864
>>  rdivide(A,C)
ans =
```

0.0835 0.1542 0.1375 0.1449 0.1596 0.0730 0.1269 0.1204
>> B1=[0.0835, 0.1542, 0.1375, 0.1449, 0.1596, 0.0730, 0.1269, 0.1204;0.1542, 0.1375, 0.1449, 0.1596, 0.0730, 0.1269, 0.1204, 0.0835; 0.1375, 0.1449, 0.1596, 0.0730, 0.1269, 0.1204, 0.0835, 0.1542;0.1449, 0.1596, 0.0730, 0.1269, 0.1204, 0.0835, 0.1542, 0.1375; 0.1596, 0.0730, 0.1269, 0.1204, 0.0835, 0.1542, 0.1375, 0.1449; 0.0730, 0.1269, 0.1204, 0.0835, 0.1542, 0.1375, 0.1449, 0.1596; 0.1269, 0.1204,0.0835, 0.1542, 0.1375, 0.1449, 0.1596, 0.0730 ;0.1204, 0.0835, 0.1542, 0.1375, 0.1449, 0.1596, 0.0730, 0.1269]
B1 =
0.0835 0.1542 0.1375 0.1449 0.1596 0.0730 0.1269 0.1204
0.1542 0.1375 0.1449 0.1596 0.0730 0.1269 0.1204 0.0835
0.1375 0.1449 0.1596 0.0730 0.1269 0.1204 0.0835 0.1542
0.1449 0.1596 0.0730 0.1269 0.1204 0.0835 0.1542 0.1375
0.1596 0.0730 0.1269 0.1204 0.0835 0.1542 0.1375 0.1449
0.0730 0.1269 0.1204 0.0835 0.1542 0.1375 0.1449 0.1596
0.1269 0.1204 0.0835 0.1542 0.1375 0.1449 0.1596 0.0730
0.1204 0.0835 0.1542 0.1375 0.1449 0.1596 0.0730 0.1269
>> p=[0, 0, 0, 0, 1, 0, 0, 0]
p =
0 0 0 0 1 0 0 0
>> p1=[p*B1]
p1 =
0.1596 0.0730 0.1269 0.1204 0.0835 0.1542 0.1375 0.1449

In 2019, with a maximum probability of 0.1596, the content of manganese in the bottom waters of the reservoir will be 424.8 units.

>> p2=[p1*B1]
p2 =
0.1190 0.1266 0.1246 0.1234 0.1321 0.1234 0.1246 0.1266

In 2020, with a maximum probability of 0.1321, the manganese content in the bottom waters of the reservoir will be 811.8 units.

Discussion. As a result of the complex hydroecological study of the reservoir Ternopil Pond, the ecological hazard of the content of certain substances and the ecotoxicological situation as a whole have been assessed by comparing the indicators with environmental norms and environmental quality standards (Gandzjura and Grubinko, 2008).

The water is mainly alkaline, which contributes to the presence of carbonic acid in the form of a hydrocarbonate ion, providing an environmentally acceptable gas regime of water and the absence of obsolescent phenomena. The reason for the alkalinity of the water is the decay of organic substances in the bottom layer and the silt, as well as the salinity of the reservoir with alkaline equivalents of flushing origin (Grubinko etal., 2013).One of the critical factors in the reservoir is the accumulation of ammonia in significant concentrations (Constableetal., 2013). The water most polluted ammonia is in the areas of its stagnation near the "Nadstavna Church", behind the island from the side of "Tsyganka", near the restaurant "Khutir" and near the boat station (excess MPC almost 30 times). Less contaminated due to leakage are areas near the dam (water drain - western and eastern - sites 6 and 1) (exceeding the MPC by 10-15 times).The most polluted ammonia sludge is on the sites near the "Nadstavna Church", behind the island from the side of "Tsyganka" (exceeding the MPC by almost 100-150 times). High alkalinity of water contributes to the transition of a significant amount of ammonia to highly toxic ammonia, which degrades the ecotoxicological situation of the reservoir due to the significantly higher toxicity of ammonia compared with the ammonium ion(Romanenko 2015, Grubinko et al.,2013).

In the water, excess levels of sodium ions were found, which, along with the sum of ions of other metals, indicates the significant salinity of the pond, especially at sites of intense flushing from the shore: near the dam, from the side of the village of Bila and Krushelnytska St., from the restaurant "Khutir". The main source of salinity is the use on the roads and sidewalks of bulk salts and slags in the winter.

Polymetal contamination of sludge with high and biologically dangerous, except for iron, levels of their mobile forms and the excess over permissible levels in the most contaminated places is dozens of times above the norm. The excess of the norm of the content of the mobile mold for copper was found to be 24-86 times, nickel - from 2 to 17 times, cobalt - 4-8 times, and a high level of iron and zinc was established. The pollution of the sludge with mobile cadmium (almost 60%) and lead (almost 90%) was detected. In this case, the content of mobile cadmium exceeds the permissible norm by 5-80 times (at the site 2 near the boat mooring this norm was exceeded by 128 times), and lead - by 4.5-12. A high level of content of mobile metal forms was established at sites with a significant blackening, lower oxygen content and higher values of pH - boat mooring, from the side of the village Bila, the beach "Tsyganka", the smallest was near the dam territory and the factory opposite the hotel "Ternopil" (Gumeniuk, 2003).

Using economic-mathematical modeling based on the theory of Markov chains, we have calculated the predicted values of the content of cobalt and manganese in the bottom sediment of the studied reservoir for the next two years, which will allow monitoring of the situation regarding the content of metals in the bottom sediment of the reservoir. Also, the method of correlation-regression analysis investigated the effect of ammonium on the pH index of water, the effect is quite significant and is 86%. The coefficient of elasticity was calculated on the basis of this value. The coefficient of elasticity suggests that with an increase in ammonia by 10%, the pH index of water will decrease by 8%(Akin et al,2011; Budka, 2013).

Conclusion. Thus, regarding essential, and especially, nonessential metals, it is possible to state that pollution of the silts of the pond is polymetallic with a high and biologically dangerous, except for iron, share of their mobile forms and excess over the maximum permissible levels in the most contaminated places, ten times above the norm. In case of change in the hydrochemical balance (primarily pH index, carbon dioxide), the mobility of metals may increase, which will substantially exacerbate the virtually catastrophic contamination of the pond with extremely toxic and biologically hazardous metals. The areas most polluted with metals with a high degree of biological risk are the silty backwaters – site and the places of active surface runoff site. With the river runoff in the reservoir about half of the mobile metal form is brought, the rest is accumulating due to emissions. Knowing the predicted values of the content of such metals as manganese and cobalt, using the theory of prediction based on the theory of Markov chains, we can monitor the situation in the near future. If the hydrochemical balance is changed (first of all, pH index, carbon dioxide), the mobility of metals may increase, which will substantially aggravate the almost catastrophic contamination of the pond with highly toxic and biologically hazardous metals.

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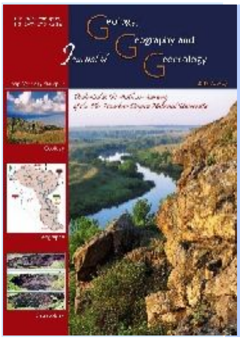

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Mapping the spatial and temporal distribution of changes in the administrative-territorial division

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Abstract. The article is devoted to the development of the content of generalized maps on the history of administrative-territorial division. The purpose of such maps is to reflect the features of the space-time distribution of administrative changes.We have found that it is better to link indicators of dynamics to such spatial objects as the territories of modern administrative-territorial units (or the territory of historical administrative-territorial ones as of a certain date), to polygons of a single history of administrative membership, to administrative-territorial units as dynamic objects.Under the polygons of a single history of administrative ownership, we mean the territories identified during the analysis, all points within which belonged to the same administrative-territorial unit at any time during the analyzed period. Unlike polygons of the smallest common geometry (used in the method of space-time composites), such objects can be allocated for different periods of time and for different administrative levels.For such spatial objects, we propose to calculate and display on the map the number of changes in administrative ownership or the total duration of belonging to some administrative-territorial unit (usually, a high level). For larger static areas than the polygons of a single history of administrative affiliation, we suggest calculating and displaying on the map the indicator of administrative variability and the average duration of ownership. In our opinion, the indicator of administrative variability should consider the size of the analyzed territory, the number and volume of spatial changes. We have developed a formula for calculating such an indicator.The indicators that we calculate for historical administrative-territorial units on the map are displayed within the static contour. However, these indicators are calculated for a dynamic object. These indicators are: the number of changes, the total number of changes in parameters, the total number of dates of change, the spatial configuration variability index, the area-weighted average area and its relation to the modern one. We propose to calculate the index of the variability of the configuration of the administrative-territorial unit as the sum of the relations of the areas of the reassigned territories to the areas of the administrative-territorial unit at the time before the change. Since different administrative-territorial units have different duration of existence, in our opinion, it is important to analyze not only the quantity but also the intensity of the changes. To reflect on the map the course of changes in the administrative-territorial unit in time, we developed a timeline-based chart.

Key words: administrative-territorial division, mapping, timelines, generalization of time-varying data, spatial and temporal distribution of changes

Картографування просторово-часового розподілу змін адміністративно-територіального поділу

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Анотація. Виявлено, що показники динаміки доцільно прив'язати до таких просторових об'єктів як території сучасних адміністративно-територіальних одиниць (або територій історичних адміністративно-територіальних одиниць станом на певну дату), полігони єдиної історії адміністративної приналежності, адміністративно-територіальних одиниць як динамічних об'єктів. Для полігонів єдиної історії адміністративної належності пропонуємо розраховувати та відображати на карті кількість змін адміністративної належності або сумарної тривалості належності до певної адміністративно-територіальної одиниці. Для більших статичних територій, ніж полігони єдиної історії адміністративної приналежності, пропонуємо розраховувати та відображати на карті показник адміністративної мінливості та середньої тривалості належності. Показник адміністративної мінливості повинен враховувати розміри аналізованої території, кількість та обсяги просторових змін. Розроблено формулу розрахунку такого показника. Показники, які ми розраховуємо для історичних адміністративно-територіальних одиниць, на карті відображаються в межах статичних контурів. Однак ці показники в дійсності розраховані для динамічного об'єкта. Такими показниками є: кількість змін конкретного виду, загальна кількість змін параметрів, загальна кількість дат змін, показник мінливості простору, середньозважена в часі площа і її відношення до сучасної. Пропонуємо розраховувати показник мінливості конфігурації адміністративно-територіальної одиниці як суму відношень площ перепідпорядкованих територій до площ АТО на момент до зміни. Обґрунтовано доцільність аналізу крім кількості змін їх інтенсивності. Для відображення на карті змін адміністративно-територіальної одиниці в часі розроблено діаграму на основі таймлайну.

Ключові слова: адміністративно-територіальний поділ, картографування, таймлайни, узагальнення різночасових даних, просторово-часовий розподіл змін

Introduction. In independent Ukraine, the interest to the topic of administrative-territorial division (ATD) in general and history of its development in particular increases. A scientific discussion of reforming the current administrative division goes on in the country. However, in retrospective studies on the administrative division of Ukraine, the cartographic method of study and modern geoinformation techonogies were not used broadly. The maps of the history of the administrative division are available in many history atlases, and also in particular scientific works (Trotsenko, 2008). Nonetheless, in content, they are mostly combinations of the borders in different periods on a single map or the maps which demonstrate the course of administrative changes over a short period of time. At the same time, there are no generalized maps which would reflect the pe-culiarities of spatio-temporal division of changes over a long period demonstrating the differences in the administrative history of different objects (territories).

In foreign countries, the aspects of cartography of the spatio-temporal division of the administrative changes are also insufficiently developed . Some cartographic works demonstrate the changes in the situation using special graphic models, for example the timelines in the GeaCron Atlas (this is not on the map, but presented as additional information), theoretical aspects of developing such graphic models for political territorial objects were studied by A. Renolen. More developed are the issues of the history of administrative division (or political map) in the GIS data bases and their visualizations, and also general issues of the data analysis related to the ad-ministrative-territorial units variable over time. Especially notable are the studies by I.Gregory. M. Berman, M. DeMoor, T. Wiedemann, M. Nüssli, C. Nüssli, E. VanHaute and also the studies conducted earlier and general theoretic studies on the presentation and analysis of historical data in GIS, particularly Langran (1992).Some developments in the sphere of presenting data can be used and for visualizing the spatio-temporal distribution of changes. E. VanHaute considers one of the advantages of describing changes in ATD using the method of "least common geometry" (LCG), also known as "space-time composite"or"spatiotemporalcomposite"(STC) to be the opportunity of using LCG polygons for studying the changes in the attributive data over time (VanHaute, 2005). That is, the LCG polygons are considered not only as the units of data maintanence for the next aggregation and depiction of the administrative units of higher levels, but as the spatial basis for the attributive data and their visualizations.

The goal of the study was to develop a content (objects of mapping, parameters) and graphic tools for creating maps which demonstrate the peculiarities of spatial and spatio-temporal division of administrative changes and duration of the administrative belonging.

Materials and methods. The study is methodological and was made on cartographic and text materials on the history of administrative-territorial division of Dnipropetrovsk Oblast. During the development of the approaches for mapping the spatio-temporal division of administrative changes, we followed the idea of division of the administrative-territorial units into smaller polygons, which lays in the basis of the method of spatio-temporal composites and the method of visualizing the course of events in time, known as timeline.

Results and their analysis. The parameters which characterize the level of ATD dynamic can have different spatial localization and be calculated for static polygon objects, for dynamic polygonal objects, linear objects, points of regular network, etc. (Havriushyn, 2018).

As static polygonal objects, we can consider the territories located within administrative borders. They can correspond to the administrative-territorial unit (ATU) either at a certain date or be a result of generalized borders of ATU over different periods of time.

Among static polygonal objects created as a result of generalizing the borders of an ATU over different time periods, special significance belongs to the polygons of the common history of administrative belonging (CHAB) - a territory, all points of which belong to the same historical ATU in every moment of the period of study.

Dynamic polygonal objects are historic ATU in time dimension (Table 1)

Table 1. The objects of cartography and the parameters on the maps of spatio-temporal division of changes in ATU

	Objects of mapping		
	ATU in variable borders	Territory of current ATU (as at)	Polygons of CHAB
Map purpose	Visualizing of the individual peculiarities of history of different historic ATU	Demonstrating changeability of the administrative belonging of the territory within the borders of current ATU or historic belonging recorded for a particular date	Demonstrating distribution of the number of changes and duration of administrative belonging in the area
Parameters (characteristics) of the object	Duration and chronologic frames of existence, area, type, name, administrative centre	Parameter of administrative belonging	Total number of associations, total number of ATUs they belonged to, duration of belonging to ATUs

Polygons of CHAB (Fig. 1) are the most suitable for mapping the division of the number of changes in administrative belonging (re-associations) or duration of belonging to a certain object (ATU). Maps of number of re-associations (or num-ber of ATUs the territory belonged to) by polygons of CHAB enable depiction of spatial division of administrative changes and determination of territories more or less stable in administrative context. Maps of long belonging of territory to ATU by polygons of CHAB demonstrate peculiarities of formation of borders of ATU, particularly allow distinguishing the "historical kernel" - a territory which always remained within a studied object and borders of territory ever included in the ATU.

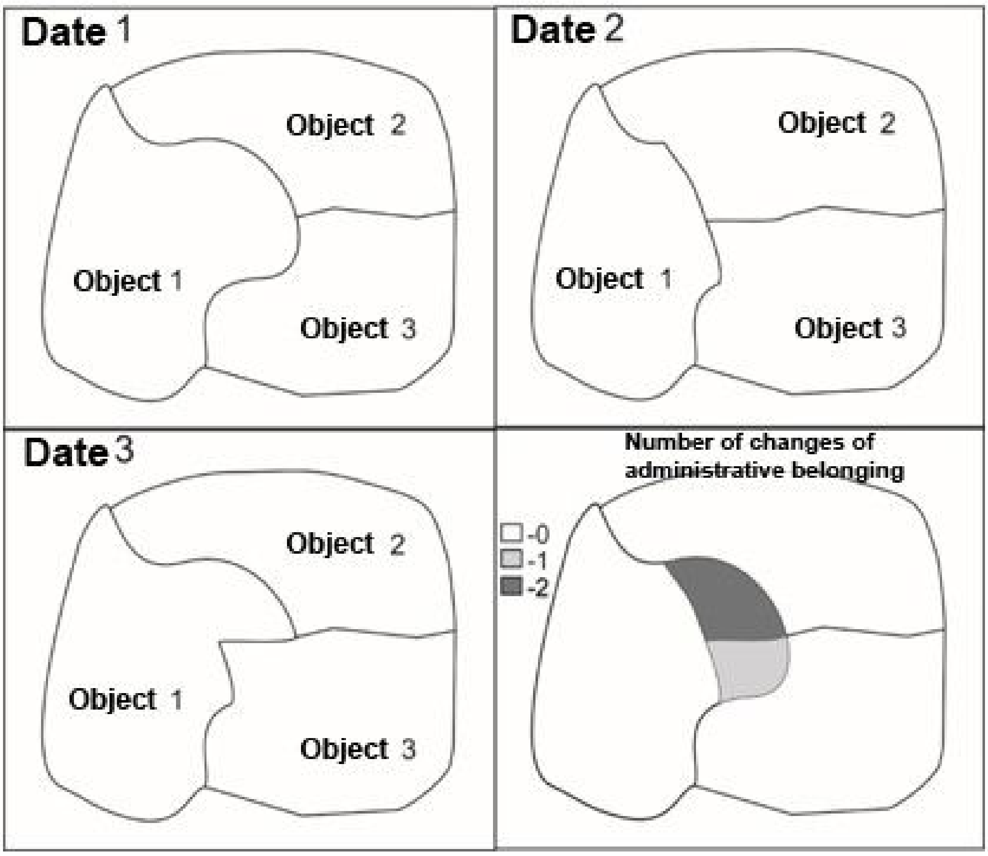

Fig. 1. Distinguishing polygons of common history of administrative belonging and visualization of the number of administrative changes

To automatise the process of creating polygons of CHAB in GIS for ATD history, we created a program module using Mapbasic language. The algorithm of creating CHAB polygons is as follows. The program selects polygons which represent the contours of the ATU described by the user (or of the entire region or all ATUs - depending on the purpose), converts them to polylines and unites into a single object. Then, using a "polygons-close" function, CHAB polygons should be created between the lines of administrative borders.

Such algorithm was also used in other GIS on the condition that their bases contain ATU polygons created already. If a base contains LCG-polygons, using which ATU polygons for different dates can be created, these polygons can be used. However, if the period of study on the changes is shorter than the one covered in GIS, mapping of changes by LCG-polygons will lead to excessive fragmentation of space. Therefore, the territories which really did not differ in their history of administrative belonging over an analyzed period will be divided by borders. This is explained by the fact that differences occurred in other periods, and this is reflected in LCG polygons which are distinguished during the entire period, in contrast to CHAB polygons which are distinguished in a particular context. Therefore, it is best to enlarge the net from LCG to CHAB polygons.

In some cases, the alternative of CHAB polygons for mapping the division of the number of administrative re-associations can be the points of regular network or creating isolines on their bases, although CHAB polygons, due to the fact that they are formed by fragments of historical administrative borders which really existed, reflect the borders of areas with different number of changes most accurately, unlike regular network of isolines or raster palettes created using the points.

The algorithm of calculation of the number of re-associations, number of objects, CHAB polygon belonged to, or duration of long belonging depends on the spatio-temporal database, on the basis of which the mapping is conducted. In GIS database, ATD of Dnipropetrovsk Oblast contained ATU polygons created for different dates. Polygons which reflect the same ATU have a common code. Therefore, the algorithm of calculation of number of re-associations is as follows. Out of the ATU layer, ATUs are selected for each CHAB polygon, which contain this polygon (using SQL-requests with ContainsorWithin operators). Countoperator calculates the number of records and subtracts 1 from the obtained value. If at the same time, one unites the ATU records by code and uses Count operator for the obtained selection, instead of the number of re-associations, one will obtain the number of ATUs the CHAB polygon belonged to. For calculating duration of a CHAB polygon belonging to a selected ATU, one should select all polygons which contain this CHAB polygon, and sum the difference of "Date_final" and "Date_initial" lines for each of the records.

Sizes of CHAB polygons are usually small compared to an ATU and significantly vary, their number on the map can reach several dozens (depending on size of the studied territory and period of study). Significant differences are possible also in the value of the parameters which are being mapped. Therefore, for visualization at automised creation of maps using GIS, it is best to use a special sample "ranges" between diagrams with absolute scale.

Division of temporal administrative belonging and duration of belonging of a territory to certain objects can be determined also by static objects larger by CHAB polygons. In our opinion, the relevant issue is developing maps which would show peculiarities of ATD history within current ATUs. However, the total number of re-associations for these spatial objects, in contrast to CHAB polygons is not representative insofar as at a particular date, it is not an entire object that is being re-associated, but only a part of its territory.

Therefore, there was developed a special parameter of temporality of administrative belonging of a territory, which takes into account the number of territorial changes within an ATU, the area of these changes and the area of the ATU territory. Because any ATU territory with an area of S can be divided into n CHAB polygons with $s_1..s_n$ areas, each of which is characterized by a certain number of $p_1..p_n$ re-associations, the parameter of administrative temporality can be calculated as a ratio of the sum of the products of multiplying the CHAB polygon areas (s_i) (within the ATU) by the number of re-associations (p_i) they underwent to the total area of ATU (S).

$$m = \frac{\sum_{i=1}^{n} p_i * s_i}{S} \quad (1)$$

The numerator in the fraction of the formula (1) is the total area of all re-associated territories which were located within ATU territory during different time periods. This parameter has an individual value, although, taking into account different areas of ATU, to compare the temporality of administrative belonging, it is better to use parameter m.

Taking into account that each CHAB polygon is characterized by individual duration of belonging to an ATU (t_i), the averaged parameter (mean value) of the duration of belonging can be determined for a particular date (current condition) within its contour. This can be an absolute indicator - number of years over which on average its territory belonged to the object (2), and relative indicator - ratio of the years over which on average its territory belonged to the object to the duration of the object‘s existence.

$$T = \frac{\sum_{i=1}^{n} t_i * s_i}{s} \quad (2)$$

Research on the dynamics of ATD by fixed polygonal contours does not cover many aspects related to the peculiarities of historical changes of ATUs as dynamic objects. Therefore, the parameter of administrative temporality within an administrative district characterizes this territory, but not the dynamic of the ATU itself, the borders of which changed and did not match the current ones, and the time of existence can be much shorter than the period for which the value is calculated. Also, an ATU have non-positional (attributive) characteristics, the changes of which also should be studied.

Therefore, it is practical to develop a series of maps which would reflect the peculiarities of the history of the ATUs (as dynamic objects) in different periods. These periods are distinguished individually for the history of the ATU of a certain period. On such maps, it is possible to show administrative borders at a particular date, or borders of the ATU for different dates (for example, borders of each ATU in minimal sizes - to cover more historical objects) and visualize particular indicators of historical ATUs within the depicted borders.

Because the parameters of historical ATUs on the maps are calculated for dynamic objects, and are depicted within fixed contours, such maps cannot be considered as those which should be made using the tools of cartography and diagrammatic maps, at least in the classic sense.

The dynamic of an ATU, in our opinion, can be expressed using the following parameters: number of changes of particular type, total number of changes in parameters, total number of dates of changes, parameters of temporality of the spatial configuration, average area in time and its ratio to the current area.

Let us analyze in more detail the parameter of temporality of spatial ATU configurations. Similarly to the parameter of temporality of administrative belonging of a territory with fixed borders m, this indicator should cover the number of territorial changes the object underwent, the extent of these changes and area of the object. However, in this case, the area of an object is variable. Therefore, we suggest calculating the parameter of temporality of ATU configuration as a sum of ratios of the re-associated territory to the area of ATU at the moment of change.

For ATUs as objects which have different duration of existence, it is relevant also to calculate not only the parameters of the number of changes, but also their intensity. Such parameters can be deter-mined by dividing the parameter of number of changes by the duration of the ATU’s existence.

The approaches described above allow demonstration of the peculiarities of spatial division of changes or duration of the belonging, but not the course of these changes over time (if not taking into account the possibility of developing a series of maps - for different periods).

To show the peculiarities of temporal division, one can use special diagrams on the basis of timeline.

Such diagrams can indicate:

time over which (when) the first long period of changes took place (change);

qualitative characteristic of the object;

quantitative characteristic of the object.

Comparison of the maps indicating the course of changes in an ATU over time and total number of changes is demonstrated in Table 2.

Duration of a certain process can be demonstrated by a section (sections) of horizontal line parallel to the time scale with corresponding length and position in relation to scale. Dates of changes (events) can be demonstrated with special indicators on the time scale or in "tracks" parallel to it.

Except the horizontal scale, quantitative changes can be demonstrated using the vertical scale. As an alternative, one can develop a graduated scale and demonstrate the value by thickness of the line (for long process) or size of the intersections (for instant change).

Because the change in area of an ATU involves either loss or gain of territory, the graph of change in the territory does not always demonstrate the extent of spatial changes adequately. In some cases, if lost or affiliated territories are insignificantly different in area, the ultimate area of the object undergoes the least changes while having significant changes of its spatial configuration. Therefore, to demonstrate the extent of spatial changes, it is best to show not the general area, but the area re-associated at different dates, or both parameters.

Qualitative characteristics can be divided into individual and those which are used for all objects from a short list. Individual parameters are the ATU‘s name, its administrative centre. The other parameters include type of ATU. It can be demonstrated using colours for its "lines of existence".

Table 2. Parameters of historical ATUs which are being mapped

Characteristics of ATU	Parameters which depict course of changes over time	Parameters indicated in maps, which demonstrate only spatial division of number of changes
Characteristics of time	Time of existence	Total duration of existence
Spatial characteristics	Area of territories re-associated at different dates, area of ATU at different dates	Parameter of temporality of spatial configuration of ATU, average area in time
Name (individual attribute)	Date of change of name	Number of dates when the name was changed
Type (special attribute for many ATUs)	Time period, over which the ATU had the corresponding area	Number of dates when the type was changed

Individual qualitative characteristics are hard to demonstrate on a timeline without overloading the map, therefore it is best to show only the facts of their changes. These qualitative characteristics which are typical simaltaneously for different objects on the map and values which are not large can be depicted using colour or other graphical changes in timeline. Variants of the timelines, which we developed for demonstrating the course of changes in an ATD are presented in Fig 2 and Fig 3.

Therefore, for the territory within an ATU for a date of reference (current condition), one can reflect the percentage of the entire territory occupied by a corresponding ATU in different periods of time. For example, Novomoskovsk District in some years covered only a half of its modern day territory. Also an interesting fact is that a part of dynamic ATU in different time instances was located within its current contour. For CHAB polygons, a diagram can be developed, demonstrating division of number of re-associations over time or in timelines of belonging to a certain ATU (ATUs). However, taking into account peculiarities of sizes of such polygons, using such diagrams is not always possible for maps with large territorial coverage. By contrast, it is often possible and useful for studying small territories, for exam-ple, within several administrative districts. The timeline of belonging of territories in such case allows demonstration of the temporal peculiarities of formation of the territories of these areas and re-association of the territories between them. At the same time, the territory of "historical kernel" can be avoided, so the map focuses on the territories which changed their administrative belonging.

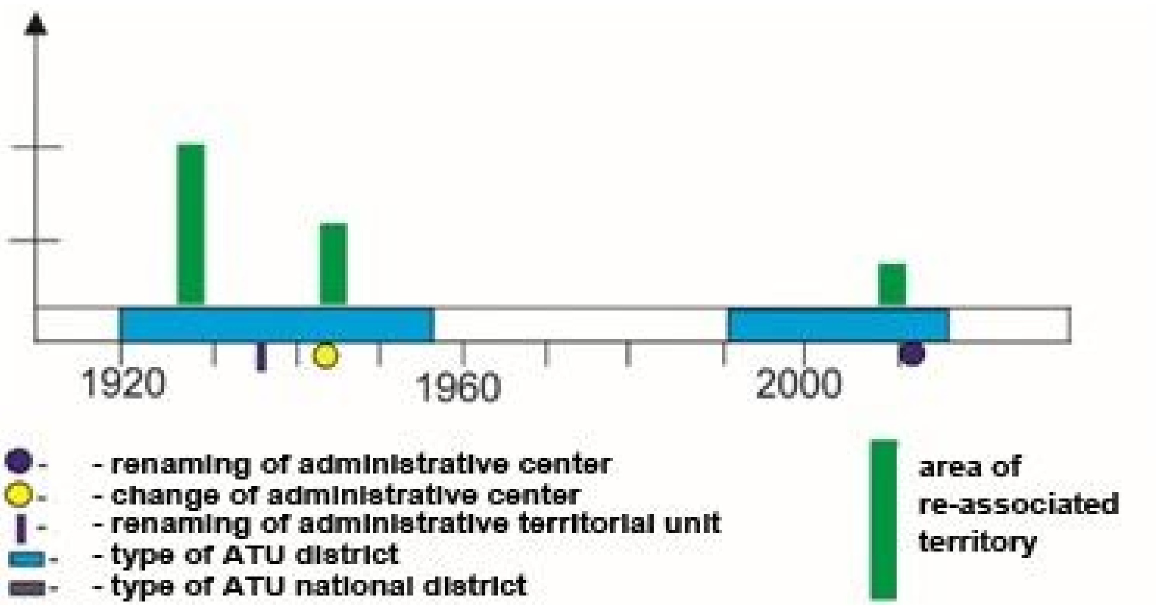

Fig. 2. Variant of timeline history of administrative-territorial units (only the re-associated area is demonstrated).

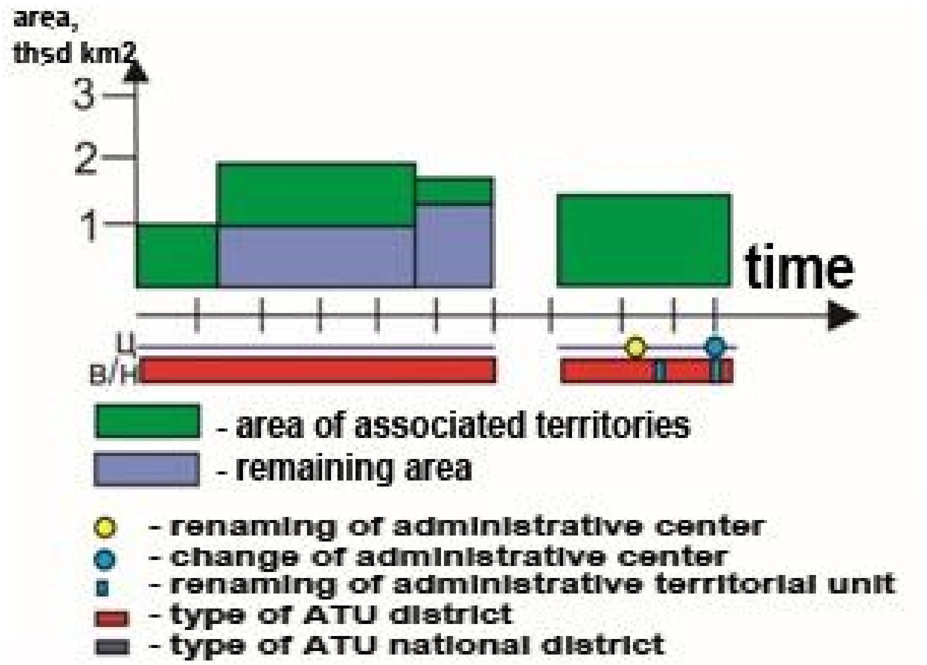

Fig. 3. Variant of timeline of history of administrative-territorial unit (demonstrates the area of associated territories and the area remaining after the change)
In some cases, diagrams of changes in time can be used for static objects which were analyzed above.

The diagrams described above cannot be developed using standard methods of available software, therefore we developed a program of our own, for MapInfo platform for developing maps with such diagrams. They form on separate layers out of spatial objects. Base objects are key points - indicators of change, latitude of which corresponds to the latitude of the ATU centroid, and coordinates of longitude are determined as X0+ΔX, where X0 – longitude of the initial (last on the left) point on the timeline, ΔX – shift to the right, calculated as difference between temporal value of the initial point and temporal value of the current point, converted to distance by longitude (Table 3). It should be mentioned that for large territories and particular projections, one might need to take into account peculiarities of projection in calculating the longitude of point objects on the timeline.

The size of the time scale for objects on the map is determined by minimum initial date and maximum final date among objects depicted on the map

Table 3. Calculation of longitude of point object-mark about event on the timeline of object

Date (d)	Longitude of ATU centroid	Longitude of the beginning of timeline scale (X_0)	Shift of date, years	Shift of corresponding point (ΔX)	Longitude of point on timeline
(From the obtained table)	Is determined using the function CentroidX(obj)	CentroidX(obj)-dX	d-min	(d-min)*M	X_0+ΔX
min - minimum initial date among all objects depicted on the map, rounded off to a lower value which would be divisible by 10 M - coefficient of converting the difference in time into the difference in longitude on graph (scale of timeline) max - maximum final date among all objects depicted on the map, rounded off to a lower value which would be divisible by 10 dX= 0.5((max- min)*M) – shift of longitude of beginning of timeline scale from the longitude of centroid of the object to the west for correspondence of longitude of the scale middle with longitude of centroid					

Key point objects which demonstrate creation and removal of objects should be connected with lines. If needed, sign points which demonstrate change of a certain parameter are indicated on particular positions on the timeline of the object on a separate layer. These point objects have one attribute - value of the studied characteristic for period which follows the date of change. That is, the basic variant of diagram is a shortened variant which does not include depiction of the characteristics, and contains only signs indicating their changes. The exception is the type of ATU which is demonstrated using colours of sections on the timeline. If needed, on the basis of signs indicating changes, which are point objects with corresponding attribute, the value of the attribute is demonstrated using standard tools of MapInfo. For example, above sign points of change in area, bar charts could be developed, and the toponyms would be demonstrated near the sign points indicating change of the name.

It should be mentioned that timelines - diagrams of division of time of existence and changes of objects over time are not very convenient for comparing the objects between one another by total parameters, for example total time of existence or total number of changes, though such parameters can be calculated using the map. To compare the dynamic of an ATU, it is better to use maps which demonstrate the total number of changes over the time period using bar diagrams.

We have automated the development of such maps by writing programs in Mapbasic language. Data for such diagrams are prepared using SQL-requests to the initial data base. Total duration of a ATU's existence is calculated as a sum of differences between final and initial date of all tuples which describe changes in ATU in the main table. Mean area over time is calculated using standard function SQL "wAvr", arguments of the function are differences between initial and final dates, and area of object on these dates, determined using "Area" function. Total number of dates of changes is calculated using SQL-request as (Count-1) with grouping by code of object. Diagrams are developed on the basis of sample available in MapInfo.

Conclusions. As a result of generalisation of data on ATU history over different periods, it is possible to see spatial and spatio-temp,oral division of administrative changes. The objects of mapping can be specially selected polygons, all points of which have the same history of administrative belonging, territory of current ATUs or territory of historical ATU at chosen date, and also ATUs as dynamic objects. In the latter case, the indicators of the dynamic are calculated for object variable in time, and depicted in recorded borders. To depict division of spatial administrative changes, it is best to use polygons of common history of administrative belonging. For such polygons, a general number of changes can be developed, indicating changes of administrative belonging or duration of administrative belonging to a particular ATU. For territories larger than these polygons, it is recommended to use other parameter of temporality of administrative belonging, which is calculated as a ratio between sum of products of multiplying areas of such polygons within the borders by number of re-associations (p_i) they underwent to the general area of the territory. There was also developed a similar parameter for an ATU as a temporal object, it includes changes in the area of the analyzed object over time. For ATUs as dynamic objects, apart from the number of changes, it is practical to demonstrate their division over time using special diagrams and timelines.

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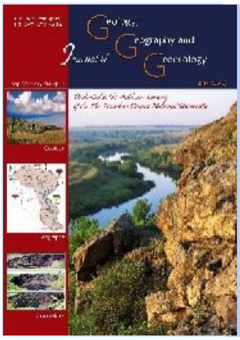

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Geo-information modelling of the insolation level within Ivano-Frankivsk region

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Abstract. Useof alternative energy sources is one of the promising directions in economic and environmental development of any territory. The purpose of this article is to conduct geo-information analysis of the insolation level within Ivano-Frankivsk region located in the western part of Ukraine. When considering any research territory, it is worth conducting a factorial analysis, which gives the possibility to characterize any advantages and disadvantages of the use of alternative energy. Justification of approaches to the study of territories where alternative energy sources are located or generated is needed to create a unified system for assessment of the potential of the renewable energy sources. According to data of the European Space Agency, the insolation level on the research territory varies from 1175 to 1425 kW/hour* sq. m/per day. The method of our research involves the statistical analysis of the insolation level and the factor approach to determining the existing level of insolation Insolation values, meteorological and geomorphological factor characteristics are used to substantiate the new methodology for calculating the existing insolation level. According to the statistical analysis and geo-information analysis, this reasonably permits us to structure months by the level of insolation as well as to calculate the insolation level at a specific point for a certain time of year. Taking into account the angle of inclination above the horizon – the Sun's declination, the slope exposure – the Sun's azimuth gives us the possibility to reduce the value of the relief point with its selected factor characteristics and the insolation value to the single coefficients, which permits us to clarify the information as to the insolation level of the selected region. Finally, this is resulted in creation of a map with the isolation levels for Ivano-Frankivsk region taking into account the factor characteristics. The map represents the changing of the insolation level for seven grouped months. It should be noted that insolation level is uneven and it is characterized by the widest gradation within the territories with complex relief. In that event, the optimal angle of solar photovoltaic module inclination equals 49° within Ivano-Frankivsk region. Such structuring clearly reflects the dynamics of changes in the insolation level for an individually selected zone. The scientific novelty of the obtained results is assessment of distribution of the solar energy potential required for further selection of areas to design and locate the solar power stations. The practical significance lies in obtaining the digital cartographic materials which allow assessment of the insolation value at a specific point in the studied region. Structuring of the insolation maps gives the possibility for further development of a unified insolation assessment scheme that is convenient for any user.

Key words: solar insolation, geo-information analyses, potential, renewable energy sources

Геоінформаційне моделювання рівня інсоляції території Івано-Франківської області

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Анотація.Використання альтернативних джерел енергії є одним із найперспективнішим напрямком економіко-екологічного розвитку територій. Метою публікації є геоінформаційний аналіз рівня інсоляції території Івано-Франківської області, яка розташована у західній частині України.При розгляді будь-якої території досліджень, варто виконати факторний аналіз, що дозволить охарактеризувати усі переваги на недоліки використання альтернативної енергетики. Обґрунтування підходів до вивчення територій розміщення та видобутку альтернативних джерел енергії викликано необхідністю створення єдиної системи проведення оцінки потенціалу відновлювальних джерел енергії. Рівень інсоляції на території дослідження змінюється від1175 до 1425 кВт/год*кв.м в день згідно з даними Європейського космічного агенства. Методика роботи полягає у статистичному аналізі рівня інсоляції та у факторному підході до визначення приведеного рівня інсоляції. Значення інсоляції, метеорологічні та геоморфологічні факторні характеристики використані для обґрунтування нової методики розрахунку приведеного рівня інсоляції. Це дозволило на основі статистичного та геоінформаційного аналізу обґрунтовано підійти до структурування місяців за рівнем інсоляції та розрахунку рівня інсоляції в конкретній точці для певного періоду року. Урахування кута нахилу схилу – схилення Сонця, експозиції схилу – азимута Сонця дозволило привести значення точки рельєфу з його вибраними факторними характеристиками та інсоляційним значенням до єдиних коефіцієнтів, які дозволили уточнити інформацію щодо рівня інсоляції обраного регіону. Кінцевим результатом є побудована карта рівнів інсоляції для території Івано-Франківської області з урахуванням факторних характеристик. Карта репрезентує зміну рівня інсоляції для семи згрупованих місяців. Необхідно відмітити, що рівень інсоляції є нерівномірним, і найбільшою градацією він характеризується на територіях зі складним рельєфом. При цьому оптимальний кут нахилу сонячного фотомодуля для території Івано-Франківської області є 49°. Таке структурування наочно відображає динаміку зміни рівня інсоляції для окремо вибраної зони. Науковою новизною одержаних результатів є оцінка розподілу потенціалу використання сонячної енергії, необхідної для подальшого вибору ділянок проектування та розміщення сонячних електростанцій. Практична значимість полягає в отриманні цифрових картографічних матеріалах, які дозволяють оцінити значення інсоляції в певній точці досліджуваного регіону. Структурування карт інсоляції дає змогу в подальшому розробити уніфіковану схему оцінки інсоляції, зручну для будь-якого користувача.

Ключові слова: сонячна інсоляція, геоінформаційний аналіз, потенціал, відновлювальні джерела енергії

Problem definition. The growth of multi-year world temperatures, which is mainly conditioned by increase in the carbon monoxide content, promotes interest in planning and sustainable development of economic activity in the country. The use of solar-cell panels is one of the effective methods of electric power and heat production. Unlike the traditional methods (such as burning of hydrocarbons, using atomic energy, etc.), they are not so widely used but arouse interest because of their environmental friendliness and renewability. The introduction and ecological justification of the solar-cell panels require the knowledge of the reduced insolation level ($I_{пр.}$) in regions as well as the factors that may influence the functioning of such energy systems. The use of geo-information systems (GIS) will offer the possibility to unify the process of selecting territories and assessing potential of the renewable energy sources (RES).

Analysis of recent researches and publications. Working out the energy-efficient programs, which are co-financed by state and international funds, allows measures to be planned for the development of alternative energy sources. These programs in their regulatory and technical aspect are governed by the State Agency on Energy Efficiency and Energy Saving of Ukraine, in accordance with the 'National Strategy 2035'(Sukhodolya, 2014).

The need to develop alternative sources as a resource base has encouraged further development in the scientific work by (Ellabbanab, Abu-Rubb, Blaabjergc, 2014). The authors have analyzed the technological basis of extraction and prospects of using alternative energy resources in future.

The problem connected with the influence of direct sunlight, as a factor of the insolation duration, and the form of buildings and structures was considered in the scientific work by Kazakov G.V. (Kazakov, 2013), in which the author has specified the morphological role of the environment.

The scientific work by (Dotsenko, 2016) shows the connection between the insolation and consumption of energy in accordance with the geographic location of the solar-cell panels, weather conditions, and seasons.

British scientists have made a significant contribution to developing the issue. They are considering in detail the solar insolation level on cloudless and cloudy days.

Their examination results show that the insolation level varies with respect to the latitude, day length, location of absorption plane, as well as extent of cloud cover (Twidell, Weir, 2015).

The amount of solar energy amount which falls on the Ukrainian territory has been analyzed according to geographical location, namely according to latitudes, in the scientific work by (Gelichy, 2015). The author has obtained empirical functional relations to calculate the solar energy reaching the Earth's surface.

There is a need for rational use of the land resources, especially of those areas which are not suitable for active economic activity but which may be used for generating alternative energy. This is especially important when there is a problem of significant negative influence over the environment (Tiapkin, Pihulevskyi, Dovbnich 2017).

Highlighting of previously unsolved parts of the general problem. Analysis of the renewable energy sources within Ivano-Frankivsk region by means of the geo-information system (Tymkiv, Kasiyanchuk, 2017) is one of the promising directions in research due to the availability of significant energy renewable potential, which is not yet exploited.

An organized system for solar potential assessment is created by means of developing a structure for selecting and analyzing factors that determine the insolation level.

Determination of a solar power plants' (SPP) potential does not depend on the solar insolation only but it is also related to a number of values of the Earth's daily rotation around the Sun. Therefore, we need to consider the factors which permit us to substantiate the new approaches to the geo-information analyses of the insolation level. Calculation of the insolation level which is conducted without regard to even one of the groups of factors does not make it possible to assess its value with a high degree of reliability, because the basic factor, the morphological characteristic of the territory, is not taken into consideration. Construction of the large energetic complexes of renewable energy is impossible without taking into consideration the tectonic and landscape factors, which in their dynamics, may significantly restrict the functioning of such solar-cell panels.

Formulating of the aim of the article (task assignment). In order to achieve the aim, we have to analyze the progress in the field of REW and the experience of using GIS for its assessment. Determination of the optimal angle of solar-cell panels permits us to develop a high-quality project for stationary energetic objects. At the same time, there is a need to draw up the morphological maps of the region, a map of the solar insolation, as well as to calculate the reduced insolation level in the chosen territory at the initial stage during development of a system for assessing the potential and expediency of using the renewable energy sources in Ivano-Frankivsk region.

Description of the methodology (the structure and sequence) for the research. The choice of territory for rational use of the natural (renewable) resources depends to the large extent on the selected type of RES. Each RES has its own spatial characteristic with the highest potential (availability of quickly renewable biological resources and areas where they are cultivated; proximity to geothermal horizons; territories that are not used for economic activity for construction of SPP, etc.).

Database creation and selection of factors (Kasiyanchuk, Chepurna, Chepurnyi, Hurtska, 2015; Kasiyanchuk, Kuzmenko, Chepurna, Chepurnyi, 2016; Suri, Cebecauer, Huld, Dunlop, 2008), structuring and analysing the data which determine one or another RES provide the possibility to conduct analyses on the example of any territory.

The insolation level depends to the large extent on geographic reference. The results of ERS permit the assessment of the full (maximum) value of the insolation according to the latitude and longitude of the selected region. Fig.1 presents the digital map of the insolation level within the territory selected for our analyses, pursuant to data by the European Space Agency (NASA, 2018). An uneven distribution of the solar energy with conditional division into seven insolation zones is shown on the map.

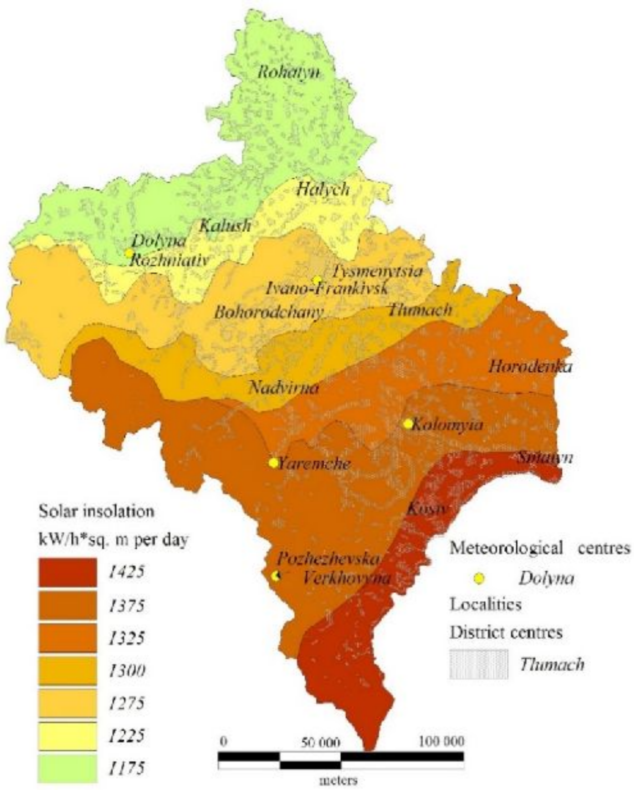

Fig. 1. Map of solar insolation of Ivano-Frankivsk region

There is a need to create a unified system for assessment of RES potential (Fig.2). It is advisable to analyze the stages of assessment of RES potential, based on the proposed scheme.

At the first stage, there is a choice of certain renewable energy sources, for which we should calculate a potential within one or another territory.

The second stage involves a well-grounded analysis of the territory where the renewal energy sources are planned to be put into production.

The third stage envisages the following: creation of the database, which includes digital topographic maps, vegetation maps, maps of tectonic disturbances, maps of meteorological conditions, etc.; insolation maps with division into zones; calculation of the factor characteristics (measures of factor determination); statistical analysis of changes in insolation level depending on selected factors.

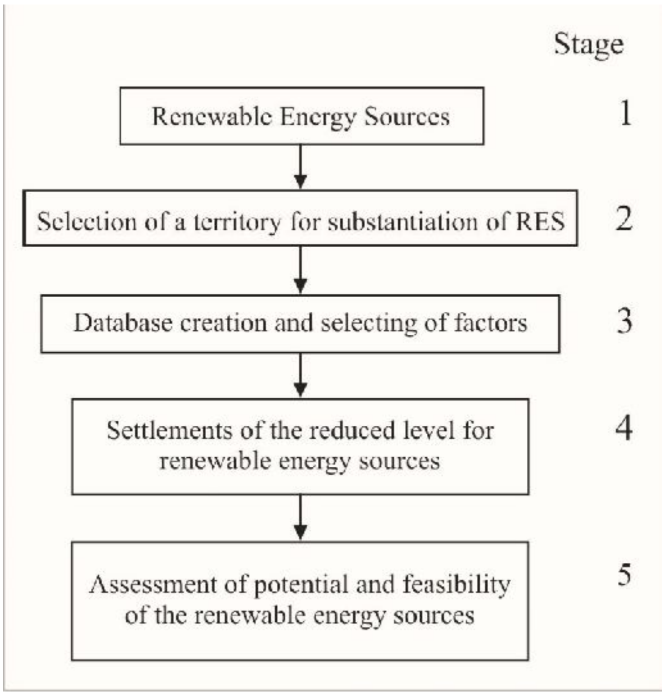

Fig. 2. Scheme of RES potential assessment

At the fourth stage, the settlements of reduced level of the renewable energy sources give us the possibility to perform calculation by using the methods of geo-information analysis and to assess the territory that may be potentially used for the energy generation.

On the basis of the above-mentioned items, the fifth stage justifies the possibilities and risks to construction of the energy facilities in terms of their special location and time dynamics.

One of the most important elements in RES analysis shall be a choice of factors influencing potential calculation.

It is necessary to take into consideration meteorological, geomorphological, tectonic, hydrogeological and landscape factors (Table 1) when constructing SPP.

At the same time, analysing Ivano-Frankivsk region according to the insolation zones (Fig. 1) includes the change of azimuth and an angle of the Sun’s inclination during the day at any point of the zone, daily movement of the Sun, and geomorphological characteristics of the selected point. This is required for calculation of the insolation level.

Let us determine the insolation in real cloud conditions for the latitude of Ivano-Frankivsk region. According to NASA [14], the average annual insolation at the latitude of φ=48° equals to 1076.7 kWh/m^2. We may determine the cloud coefficient (Table 2), which considers the morphological and meteorological factors by the ratio of insolation in real cloud conditions to insolation on a cloudless sky.

The selected point within the insolation zone shall be determined by absolute height, angle of inclination, exposure and the average insolation level within a day (where the effectiveness of solar-cell panels is above zero) and the coefficient that substantiates grouping in months according to the solar insolation (7 groups in total) (Table 3).

Table 1. Factors that influence construction of SPP

Group of driving forces		Factors	Factor characteristics
Geological		Availability of areas with breach of the geological medium (lithofacial rocks)	Distance to areas with breach of the geological medium (faults, karst, mudflows, open-cut mining)
Hydrogeological		Availability of water supply and drainage zones	Skin-factor
Meteorological		Precipitations	Intensity and frequency
		Temperature	Season temperature change
		Atmosphere pressure	Cloud coefficient, changing of atmosphere pressure (air humidity)
Tectonic		Tectonic disturbances	Distance to tectonic fault
Landscape		Vegetation	Forested area
Geomorphological		Height	Absolute estimate over the sea level
		Slope inclination	Angle of inclination of daylight surface
		Direction of slope	Slope exposition

Table 2. Insolation in cloud and cloudless conditions, kW/m^2, and cloud coefficient

Month	Insolation during cloudless sky per month	Insolation during cloudy sky per month	Cloud coefficient
January	59.21	36.89	0.62
February	86.24	54.04	0.62
March	146.32	88.04	0.60
April	188.4	110.4	0.58
May	225.06	140.74	0.62
June	231	142.5	0.61
July	221.96	147.56	0.66
August	196.23	136.4	0.69
September	154.8	91.8	0.59
October	104.16	62	0.59
November	64.2	37.2	0.57
December	48.98	29.14	0.59
Amount per year	1726.56	1070.71	-

The value of insolation is uneven throughout the year. Regression analysis, Spearmen's rank-correlation, makes it possible to see that some months are connected with each other and they are may be divided into three following groups: 1) January, February, March; 2) April, May, June; 3) July, August. There are also months that are not correlated with other months, such as September, October, November, and December.

The proximity of values is explained by the fact that the insolation level of the territory falls within a narrow range. Obviously, Spearmen's rank-correlation coefficients will show the change of insolation as a homogenous monotonic relation between recorded factors. That may be grouped by months. Significant values equal to 1 or -1.

Table 3. Spearmen's rank-correlation analyses

Month	January	February	March	April	May	June	July	August	September	October	November	December
	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
I	*1*	*1*	*1*	0,949	0,949	0,949	0,949	0,949	0,953	0,965	0,948	0,911
II	*1*	*1*	*1*	0,949	0,949	0,949	0,949	0,949	0,953	0,965	0,948	0,911
III	*1*	*1*	*1*	0,949	0,949	0,949	0,949	0,949	0,953	0,965	0,948	0,911
IV	0,949	0,949	0,949	*1*	*1*	*1*	0,983	0,983	0,995	0,983	0,966	0,957
V	0,949	0,949	0,949	*1*	*1*	*1*	0,983	0,983	0,995	0,983	0,966	0,957
VI	0,949	0,949	0,949	*1*	*1*	*1*	0,983	0,983	0,995	0,983	0,966	0,957
VII	0,949	0,949	0,949	0,983	0,983	0,983	*1*	*1*	0,970	0,983	0,966	0,957
VIII	0,949	0,949	0,949	0,983	0,983	0,983	*1*	*1*	0,970	0,983	0,966	0,957
IX	0,953	0,953	0,953	0,995	0,995	0,995	0,970	0,970	*1*	0,987	0,970	0,961
X	0,965	0,965	0,965	0,983	0,983	0,983	0,983	0,983	0,987	*1*	0,982	0,973
XI	0,948	0,948	0,948	0,966	0,966	0,966	0,966	0,966	0,970	0,982	*1*	0,956
XII	0,911	0,911	0,911	0,957	0,957	0,957	0,957	0,957	0,961	0,973	0,956	*1*

Spearman's correlation matrix includes meteorological and morphological factors. Substantiation of conditional division of the year according to the insolation level for Ivano-Frankivsk region is conducted according to the fact that the insolation provision of the territory cannot be the same because the factors of precipitation, atmosphere pressure, height, etc. in their totality have a significant influence on the level of the potentially obtained solar energy.

In order to calculate the reduced insolation level ($I_{np.}$), it is important to take into account the main condition for effective work of SPP, which is the number of cloudy and cloudless days, in the form of the relevant cloud coefficient for the studied territory. In turn, such grouping in months permits us to assert that the annual distribution of the solar energy is uneven with respect to the results of statistical analyses.

Presentation of the main material and obtained scientific results. ***Description of how to select a territory for SPP.*** Selectionof a territorymeans choosing a place with high insolation of surface. First, it depends on the geographic place of the area's location, the area's relief, the angle of inclination, and the direction of slope.

In order to use solar energy, we should know the visible path of the Sun during the day, although in most cases there is no necessity to determine the exact position of the Sun at a certain time. (Fig. 3). This, in turn, reduces the number of calculations required to determine the Sun's path, and therefore we can neglect the location's longitude. (Häberlin, 2012).

Fig. 3(a) shows the Earth rotating around its axis that passes through the points of the North Celestial Pole (N) and the South Celestial Pole (S). This axis is perpendicular to the equatorial plane of the Earth passing through the points W and E, which respectively indicate western and eastern directions. The centre of the Earth is marked with point C.

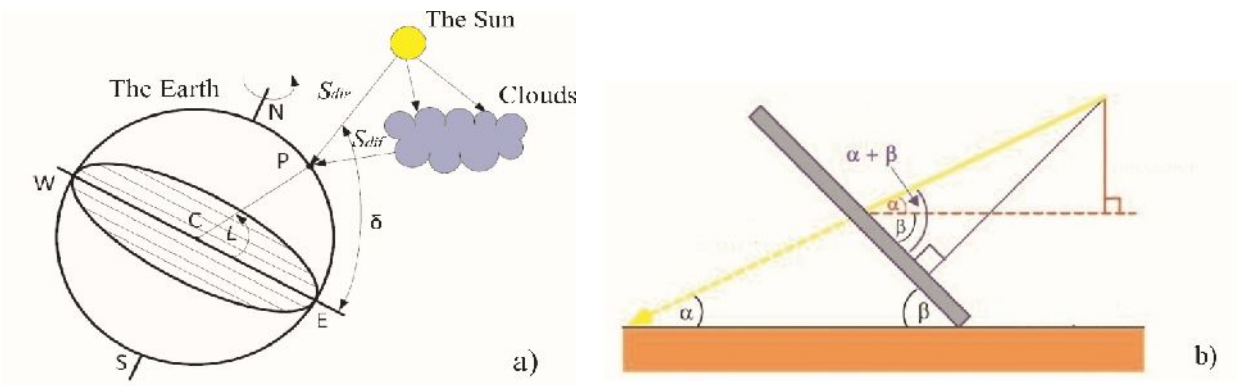

Fig. 3. Solar radiance (a), which is falling on the inclined surface (b)

Point P on the Earth's surface indicates the location of the reflect-prevention panel and it is characterized by the geographical latitude L, which equals 48° in Ivano-Frankivsk region. The angle between the direction to the Sun and the equatorial plane is called the inclination δ, which is a measure of seasonal changes.

The position of the Sun in the sky is not constant during the year because of inclination of the Earth's rotation axis with respect to the normal line to the plane of its motion around the Sun. We mark the Earth's inclination in relation to the Sun as *δ*. Thus, in the northern hemisphere, at the latitude φ=48°, at the highest point of the solstice, the Sun position can be described by value *α*:

$$\omega=90°-\delta \quad (1)$$

In order to determine the optimal value of the angle of solar module (Fig. 3b) for an area with latitude φ=48°, at which the solar module must be inclined to the horizon, initially we have to determine the average number of angles (the inclination of the Sun) for all months of the years.

$$\delta=\Sigma\eta/n \quad (2)$$

where, *η* – the average value of the angles in months, *n* – number of months.

In this case

$$\delta=(21{,}01+30{,}38+41{,}32+53{,}04+61{,}24+64{,}11+60{,}82+52{,}52+41{,}31+30{,}02+20{,}94+17{,}51)/12=41°.$$

Now, according to formula 1, we can calculate the optimal angle of solar modules' inclination.

$$\omega=90°-41°=49°.$$

Geo-information analyses of insolation level. Thegeo-morphological characteristic of Ivano-Frankivsk region is represented by the topographic maps, slope exposures, and the angles of inclination. They are built in Vertical Mapper ГІС MapInfo software environment.

Zonal insolation map (Fig. 1) is presented with morphological peculiarities of the studied region and it needs to be specified in detail.

It is obvious, that the value of the solar insolation cannot be the same throughout the region as it undergoes the influence of other natural and technological factors. Such peculiarities are described in detail and analysed above.

Understanding the features peculiar to the movement of the Sun in the sky permits us to assert that the insolation value is uneven during the day and at a certain point, which is determined by the coordinate, in particular.

The Sun's parameters, which are determinative at calculation of the solar insolation, should be reduced to the morphometric characteristics of the territory.

The angle of inclination above the horizon - the Sun's inclination, the slope exposure – the azimuth of the Sun shall be reduced to the single coefficients, which permit us to specify information as to the insolation level of the chosen region.

Thus, on the basis of the presented morphometric maps (Fig.4), we have created a number of special inquiries to determine the solar insolation level within the insolation zones (Fig. 1).

While creating inquiries, which include recalculation of the insolation level (*I*) according to the reduced level ($I_{np.}$), we have determined the effective time for obtaining solar energy per each month: January 9:00 - 16:00; February 8:00 - 17:00; March 7:00 - 18:00; April 6:00 - 19:00; May 5:00 - 19:00; June 5:00 - 20:00; July 5:00 - 20:00; August 6:00 - 19:00; September 7:00 - 18:00; October 7:00 - 17:00; November 8:00 - 16:00; December 9:00 - 16:00.

In accordance with the content of formula 1, that the value of angle of inclination above the horizon (α) and the inclination of the Sun *(δ)* cannot exceed 90° and the slope exposure *(ε)* as well as the azimuth of the Sun equal to *360°*, the following formulae are offered:

$$a=90°-(\alpha+\delta)\,, \qquad в=360°-(\varepsilon+A).$$

Then, $I_{np.}=(a/в)*I$.

The inquiries have been created under the principle of selecting the point, which contains information about the insolation level, the angle of inclination and the slope exposure relating to Sun's movement during the day (the year). The cartographic material was relatively tied to previously formed information, pursuant to the statistical analysis data (Spearmen's rank-correlation). Recalculation of the insolation value was based on the counting of the reduced insolation coefficient using special data of the point in accordance with the built relief model. More than 600 thousand points were analysed for Ivano-Frankivsk region in total.

Generating of insolation maps. The zonal map is presented on Fig. 5. The map is built by method of triangulation (central part of Ivano-Frankivsk region) and it represents the character of insolation in accordance with the grouped months.

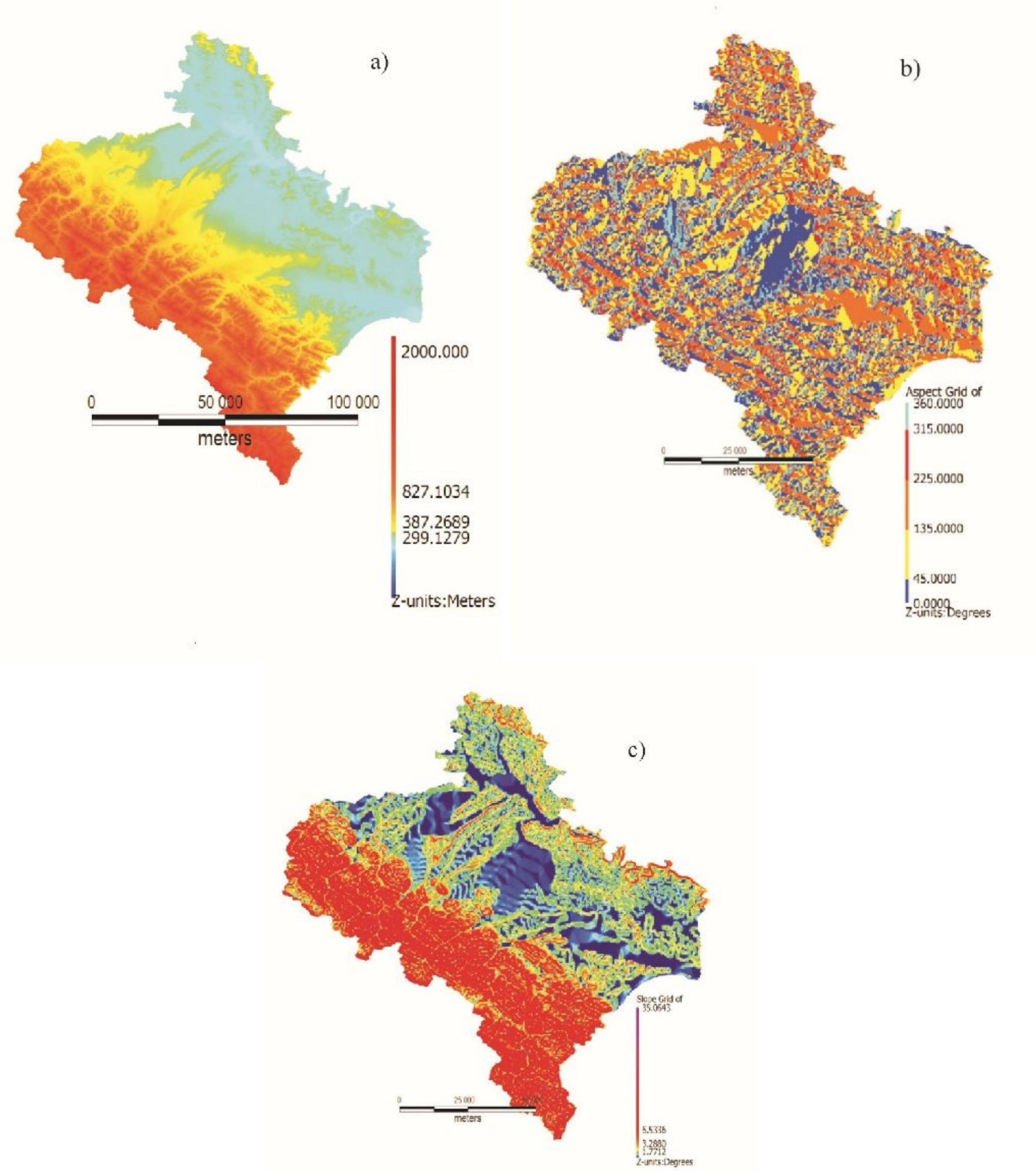

Fig. 4. Morphometric maps: *a) heights, b) exposures, c) angles*

As it seen from the figure, the level of insolation fluctuates considerably during the year. It is only natural that the values of insolation level should visually offer morphological characteristic of the territory. In this case, the maximum and minimum insolation values, which are fluctuating within the range of the daily zonal maximum (0-1425 kWh/m^2, Fig.1), present a change in the possibly generated solar energy.

Practical importance is also within the same limits but they always exceed zero and are less than 1425 kWh/m^2. This is presented on the maps (Fig. 5).

This indicates that the values of slope exposure mainly and the angle of inclination above the horizon to a lesser degree are important factor characteristics for determination of the level of insolation for any territory. The daily (visible) movement of the Sun characterizes just a degree of the absorbing capacity of the solar-cell panels, but the optimal an-gle of their location is not taken into consideration at that time.

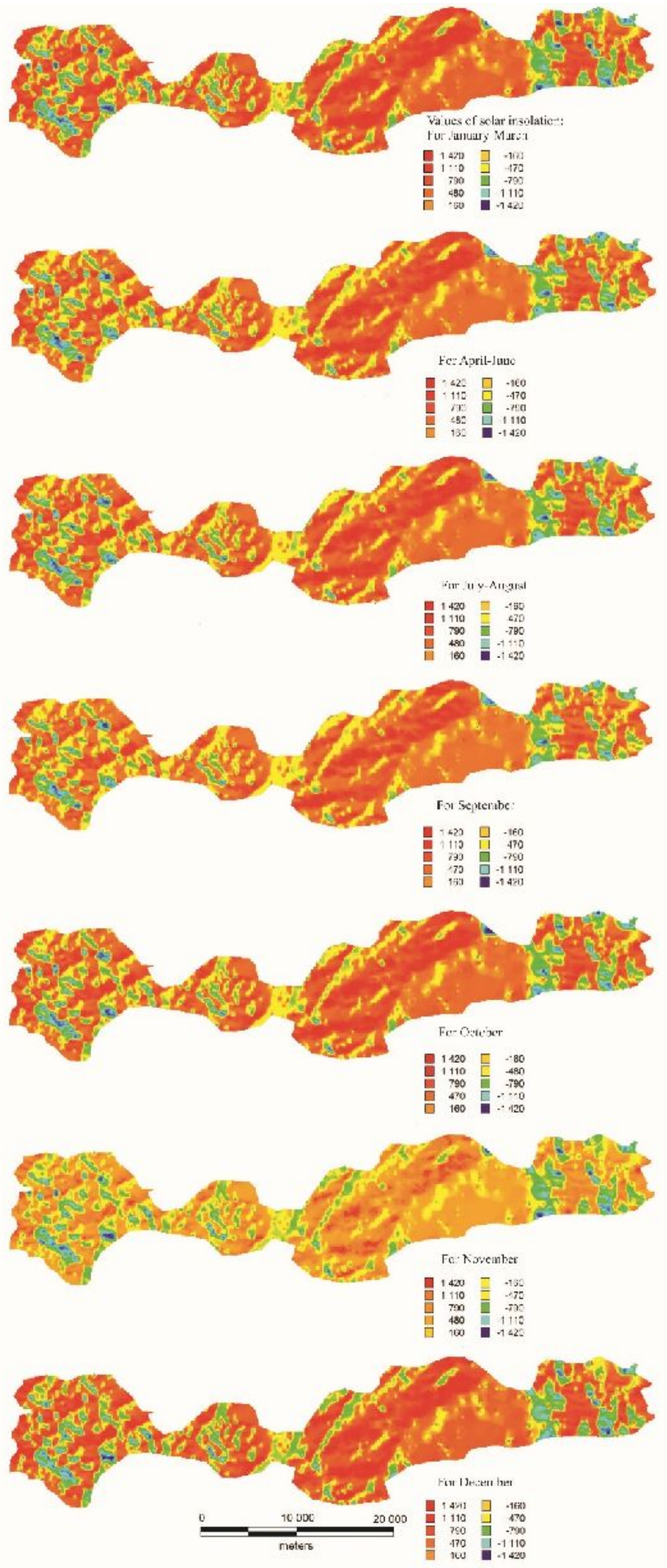

Fig. 5. Zonal maps of insolation

Conclusions and perspectives of further development of research in this direction. The cloud coefficient for each month has been calculated according to the data of reduced insolation and insolation on cloudless days. The built thematic maps of the reduced insolation for Ivano-Frankivsk region were reduced to maps of relief, exposure, and the angle of inclination in order to distribute them for the certain groups of months.

As a result, the maps with the level of insolation for the grouped months with the reduced values were built. The maps show in which way the insolation changes over the year for different conditional regions. Such maps give prerequisites for further factor analysis as to the feasibility of using and building of solar power stations in any selected territory.

Perspectives for further development of research are improvement of the quality of calculation of the reduced insolation level by means of increasing the number of re-counted points within the insolation zone and taking into account the new factors.

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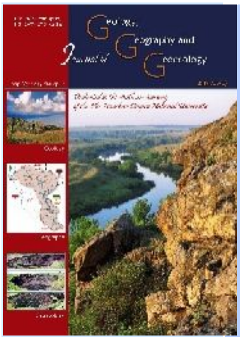

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Hydrography and hydrochemistry of the transboundary river Western Bug on the territory of Ukraine

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Abstract.The analysis of the hydrographic network of the Western Bug basin on the territory of Ukraine. This basin is estimated according to the requirements of the EU Water Framework Directive and has 2,044 rivers. Classification of the rivers of the Western Bug by area of drainage basins has shown the following results: in this basin within Ukraine there is one very big river, in fact this is the Western Bug itself. There are also three large rivers – Poltva, Rata and Luha. There are also 30 medium and 2,010 small rivers (among which 1,966 rivers have a length of less than 10 km). Theleading role of natural factors in the formation of the hydrocarbonate-calcium ion composition of the river waters of the Western Bug basin is determined. The content of the main ions and the salinity of the river waters are distinguished by a sufficiently clear seasonal character: a decrease in the spring flood and an increase in the low water level (mineralization of the water of the Western Bug – 497-573 mg/l). Mineralization of the Poltva River (the left tributary of the Western Bug), located in the same natural conditions, is significantly different: in the area of the city of Lviv (the upper reaches of the Poltva River), it reaches 784-871 mg/l, and at the estuary of the river (Busk city, at the confluence of the Western Bug) is slightly reduced - 613-670 mg/l, while in the chemical type of water, sulfates and chlorides appear. This situation is explained by the discharge of sewage from the city of Lviv into the Poltva River. In the regime of nutrients, microelements, and also specific pollutants in the water of the West Bug, no general regularities in their seasonal variations were found, which is associated with the significant idiosyncratic character of the influence of anthropogenic factors on the formation of their concentrations. We estimated the balance of substances, both natural and anthropogenic, which are carried out with the waters of the Western Bug from the territory of Ukraine (93%), as well as from the territory of Poland (7%) to the border with Belarus. The comparative methodological approach allowed us to make a quantitative assessment of the significant influence of the Poltva River on the formation of the chemical composition of the water of the Western Bug, especially in its upper part. The share of Poltva's water flow when it flows into the Western Bug is 58% of its water flow. At the same time, the share of the total ion flow is higher – 66%. The share of the discharge of individual principal ions reaches: 76% (Cl^-), 87% (Mg^{2+}) and 98% (SO_4^{2-}). For nitrogen, this figure is 68%, for phosphates – up to 80%.

Key words:transboundary river, hydrography, chemical composition of water, hydrochemical regime, ionic stream, waste of chemical substances

Гідрографія і гідрохімія транскордонної річки Західний Буг на території України

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Анотація.Наведено характеристику гідрографічних особливостей транскордонного басейну Західного Бугу на території України, гідрографічна мережа якого, оцінена за вимогами ВРД ЄС, налічує 2044 річки. Для гідрохімічних досліджень було обрано 14 створів. Мінералізація води р. Західний Буг становить 497–573 мг/л. Мінералізація води р. Полтва, лівої притоки Західного Бугу, що знаходиться в тих же природних умовах, істотно відрізняється. Так, в районі м. Львова (верхів'я річки Полтва) вона сягає 784-871 мг/л, а в гирлі річки дещо знижується – 613–670 мг/л. Ця ситуація пояснюється скиданням стічних вод м. Львова в річку Полтва. Дослідження гідрохімічного режиму р. Західний Буг та її приток за головними іонами виявили чітку залежність від гідрологічного режиму. Це пояснюється впливом зміни ролі різних видів живлення річки протягом року. Середньорічний іонний стік Західного Бугу з території України становить 793,5 тис. т або 78,3 т/км^2; з території України та Польщі – 857,0 тис. т. Таким чином, на цій ділянці річки 93 % іонного стоку виноситься з території України і 7 % – з території Польщі. Частка водного стоку р. Полтва при її впадінні в Західний Буг становить 58 % його водного стоку. В той же час, частка іонного стоку р. Полтва досягає 66 %. Для загального азоту цей показник збільшується до 68 %, для фосфатів – до 80 %.

Ключові слова: транскордонна річка, гідрографія, хімічний склад води, гідрохімічний режим, іонний стік, стік хімічних речовин

Introduction. According to the hydrographic zoning of Ukraine, 9 river basin districts have been identified on its territory, one of which is the area of the Vistula basin, from which the river flow is directed to the Baltic Sea (about 2% of the territory of Ukraine). The area of the Vistula basin in the Ukrainian territory consists of two sub-basins: The Western Bug and the River San (Vodnyikodeks Ukrainy, 1995; Khilchevskyi, Hrebin, 2017). The basin of the Western Bug is located on the territory of three countries - Ukraine, Poland and Belarus. For 47% of its length (363 km), the river is transboundary - the state border of Poland and Ukraine, as well as Poland and Belarus, cross the river (Zabokrytska et al., 2006).

The Western Bug River lies in the sphere of interests of many researchers, primarily as a transboundary basin, where it is necessary to unite the efforts of the representatives of Ukraine, Belarus and Poland with the participation of the European Union structures in addressing water management issues (Karpuk, 2015; Khilchevskyi et al., 2016; Tränckner J. et al., 2012; Hagemann N., et al., 2014). Considerable attention is paid to the issues of anthropogenic impact on water quality and the ecological situation in the Western Bug basin (Charakterystykawod, 1999; Bug River Valley, 2002; Tokarchuk, 2011; Ertel et al., 2012; Tatukh et al., 2012; Starodub et al., 2013; Dzham, Danilyuk, 2017).

General hydrographic characteristic. The Western Bug River (in Polish – Bug) is the left tributary of the river Narew, which flows into the river Vistula (the Baltic Sea basin). The total area of the West Bug basin is 39,420 km^2, the length of the river is 772 km. According to the West Bug Basin Management of Water Resources of the State Agency of Water Resources of Ukraine, the area of the Western Bug basin in Ukraine is 11,205 km^2 (over 28% of the total area of the basin), the length of the river is 404 km (over 52% of the total length), of which 220 km - the section of the river along which the border of Ukraine and Poland passes (Zakhidno-Buzke, 2017; Khilchevskyi et al., 2016).

In Ukraine, there are the source and the upper course of the Western Bug (Fig. 1). The source of the river is located within the Main European Watershed, on the northern outskirts of the Volynian-Podolian Upland in the Koltovskaya Basin near the village. Verkhobuzh, Zolochiv district, Lviv region. Between the source and the town of Ustyluh in the Volyn Oblast, the river is submontane, flows at an elevation - accross a hilly, rugged terrain. Below the city of Ustyluh, the Western Bug flows along the western outskirts of the Polesia lowland in a wide valley and has a pattern of a typical plain river.

The Ukrainian part of the basin of the Western Bug lies within the two administrative regions of Ukraine – Lviv and Volyn. Geographically, on the south-west, it borders with a basin of the San river (Vistula basin), in the south - with the river basin of the Dniester, and with a river basin of the Pripyat in the east. In the west, the Ukrainian part of the Western Bug basin reaches the state border of Ukraine and Poland, in the north - to the state border of Ukraine and Belarus.

The hydrographic network of the Ukrainian part of the Western Bug basin has 2,044 rivers. In the Water Code of Ukraine, these rivers are divided according to catchment area into: large - over 50,000 km^2; average – 2,000-50,000 km^2; small - less than 2,000 km^2 (Vodnyikodeks Ukrainy, 1995). According to this classification, the Western Bug River is an average river, and all its tributaries are small rivers.

At the same time, the classification of rivers by catchment area according to the Water Framework Directive (WFD) of the European Union, which is also used in Ukraine as a standard for assessing the ecological state of surface water masses, differs significantly: very large rivers – over 10,000 km^2; large – 1,0-10,000 km^2; average – 100-1,000 km^2; small – 10-100 km^2 (Directive, 2000/60/EC).

The application of the EU WFD type classification in the Ukrainian part of the Western Bug Basin shows the following: there is one very large river within the basin in Ukraine, the Western Bug, and three large rivers – Poltva (1,440 km^2, 60.0 km), the Rata (1,820 km^2, 76.0 km) and the Luha (1,351 km^2, 89.1 km).

Fig. 1. Map of the basin of the Western Bug river on the territory of Ukraine, Poland and Belarus (Zakhidno-Buzke, 2017)

If the Poltva and Luha basins are completely located within Ukraine, the Rata originates in the PodkarpackieVoivodeship of Poland, a few kilometers from the Ukrainian-Polish border, respectively, and the upper part of the river basin with an area of about 50 km^2 is located in the neighboring state.

Within the Ukrainian part of the Western Bug basin, according to the EU WFD classification, there are also 30 medium rivers (with a catchment area of 100-1,000 km^2) and 2,010 small rivers (up to 100 km^2). Among the small rivers, 44 watercourses have a length of more than 10 km, and 1,966 small rivers have a length of less than 10 km.

Factors of the formation of chemical composition of the river waters. A distinctive feature of *the geological structure* of the catchment area of the Western Bug in Ukraine is the occurrence of erosion of the Upper Cretaceous carbonate rocks above the local bases, which are represented by significantly fissured and karstic limestones and marls, the influence of which determines the formation of the salt composition of the river (Khilchevskyi, Kurylo, Sherstyuk, 2018).

The basin relief is characterized by incised, erosional forms of the Volynian-Podolian Upland relief, as well as flat and flat-hollow forms on the Polesia lowland. In addition, the karst forms of the relief are widespread on the areas where the carbonate rocks are bedded closely to the surface of.

The climate of the basin is moderate continental. The distribution of the annual amount of atmospheric precipitation within the catchment area of the Western Bug with a significant total wetting of the territory is uneven and exceeds the evaporation. Areas with the highest precipitation values are in the upper reaches of the river (annual precipitation is –800 mm). With a decrease in the al-titude of the catchment area, the amount of precipitation decreases to 650 mm.

Soils in the basin are mainly podzolizedchernozems, in the floodplain of the river – soddy, marshy, characterized by a light mechanical composition (light loamy, sandy loamy). In such soils, in the conditions of humid climate, a washing regime is formed, which does not contribute to the increase in the mineralization of water.

The hydrogeological conditions of the territory of the Western Bug basin are determined by its belonging to the Polish-Lithuanian artesian basin, the northern and central parts of which are characterized by significant groundwater reserves. The conditions for the formation of groundwater in the basin are generally favorable. Due to the structural features of the water, Quaternary and pre-

Quaternary sediments have a direction of movement from south to north.

*Water consumption and water disposal.*The formation of hydrochemical characteristics is significantly influenced by economic activity (ploughing, land improvement, water consumption, wastewater discharges, etc). The most significant factors which affect this basin are water consumption and water disposal.

In the 2000s, there was observed a decrease in the water consumption in the basin of the Western Bug, as in Ukraine in general. The basic structure of water consumption during that period in the basin of the Western Bug by different spheres remained practically unchanged. According to the State Agency for Water Resources of Ukraine, in 2015, it was as follows: 54% – housing and municipal services; 15% – the industry; 30% – agriculture; 1% – other needs.

The largest water consumption in the basin was recorded in 1992 – 135 million m^3; in 2001 – 115 million m^3 (Zabokrytska, Khilchevskyi, Manchenko, 2006). In 2015, according to the State Agency for Water Resources of Ukraine in the basin of the Western Bug, 90 million m^3 of water were collected, of which 20% were the surface waters, 80% were groundwater. Accordingly, the maximum discharge of wastewater was also recorded in 1992 – 245 million m^3; 2001 – 195 million m^3; 2015 –180 million m^3. It should be mentioned that the indicator of wastewater discharge in the Ukrainian part of the Western Bug basin is twice as high as the same parameter of the water intakes. This is because Lviv consumes water both from the basin of the Western Bug and from the Dniester Basin, and all wastewater is discharged into the river system of the Western Bug.

The largest source of wastewater discharges in the West Bug basin is the city of Lviv with a popu-lation of 728 thousand people as of January 1, 2017. The annual volumes of sewage of this city, which enter the Western Bug through the river Poltva which flows into it near the town of Busk, make over 80% of the total volume of sewage that is discharged in the Ukrainian part of the basin.

Other anthropogenic factors. A number of mines of the Lviv-Volynhian Coal Basin function in this territory – Chervonohrad (population of 67. 2 thousand people), Novovolynsk (52.6 thousand people); 40% of the surface of the basin was previously drained, 80-90% of the drainage water receipts were straightened; The plowed area is almost 42%.

Hydrological conditions. In the upper reach, the valley of the Western Bug has terraces (width – 1 - 3 km), the floodplain of the river is swampy, and there are oxbow lakes. The streambed is sinuous (width up to 8-15 m), and channeled in some areas. The drainage density in the territory of the Lviv Oblast is 0.35 km/km^2. In the middle of the river, the width of the valley reaches 3-4 km, the floodplain is manifested insignificantly. The width of the channel reaches 40 m. Towards the lower part of the stream, the Western Bug narrows to 1.0-1.5 km, usually, the streambed width is 50-75 m, and in some areas reaches 100 m. The stream gradient equals 0.3 m/km. The speed of the current in LvivOblast is 0.3-0.6 m/s, and decreases to 0.1-0.2 m/s in the Polesia part, which is related to a slight decline of the surface. In the basin of the Western Bug (within the Volyn Oblast) there are over 80 lakes with a total area of92 km^2, and the drainage density is 0.22-0.35 km/km^2.

For the hydrological regime of the Western Bug, a distinctive feature is significant spring flood and low summer-autumn and winter drought flows which are characterized by low water content and considerable duration. Different degrees of karst development and swampiness in some areas of the basin determine the natural regulation of water runoff, especially during the spring flood. Therefore, in the territories with karst and marshes in the same region, the average multi-year spring runoff differs in 1.5-2.0 times. Within the Lower Polesia, the influence of karst on the formation of spring runoff characteristics is the least. Therefore, the largest layer of spring flood runoff is typical for the rivers of this region (the Rata, the Zheldets and the Solokiya) – 129 -158 mm and exceeds their value for the rivers of the Podolian Upland (the Poltva, the Holoivka, the Kamenka) – 93 -115 mm.

The drought flow runoff from the rivers of the Western Bug basin occurs due to ground waters of marl and chalk (karst) and limestone strata. With its water reserves, this water-bearing horizon provides a long-term and sustainable supply to the basin's rivers during periods of absence of surface runoff. Dur-ing summer-autumn drought flow, the values of the runoff layer are higher (104-122 mm) compared to winter drought flow.

The following average annual water discharges in the Western Bug by the drains: Sasivvillage (the upper reach of the river) – 1.12 m^3/s; Sokal – 29.5 m^3/s; "Border-3" – 52.3 m^3/s (conditional drain at the border of Ukraine, Poland and Belarus, the closing drain in the Ukrainian part of the basin) (Zabokrytska, Khilchevskyi, Manchenko, 2006).

For the Western Bug, there is a significant intra-annual variability in sediment runoff. During the spring flood tide, the river carries 50% of the annual amount of suspended matter, and in the summer-autumn and winter drought flow, 30 and 20%, respectively.

Hydrochemical regime. To characterize and evaluate the hydrochemical regime of the rivers of the Western Bug Basin, 14 drains were selected: 7 on the Western Bug (above and below or within the boundaries of the cities of Busk, Kamianka-Buzka, Sokal) and 7 on the tributaries (the Poltva River – Lviv and Busk, the Rata River –Mezhirichia village; the Solokiya River – Chervonograd; the Luha river – the city of Vladymyr-Volynskyi). We analyzed a series of examinationss of the chemical composition of water for the period of 1971-2015, obtained by the Hydrometeorological Service of Ukraine (which since 2012 is in the system of the State Service of Ukraine for Emergencies). The initial long-term information for each monitored drains was grouped by the main seasons: spring high water, summer-autumn and winter drought flow. This allowed us to determine genetically homogeneous pieces of information that characterize the periods with the predominance of certain processes of formation of the chemical composition of the river waters under the influence of seasonal changes.

The article describes the chemical composition of the water of the Western Bug River as an average value for 7 drains. On the river Luha, the averaged values were calculated for 3 drains. The Poltva River was characterized by two drains: in Lviv (the upper reach of the river) and Busk (the mouth of the river) for there are significant differences between them in the chemical composition of the water.

Study of the hydrochemical regime of the Western Bug and its tributaries by the main ions revealed a clear seasonality, which is explained by the influence of the change of the role of different types of support throughout the year.

The lowest values of the total mineralization of the Western Bug water were observed during the spring flood (497 mg/l); In the periods of low-water, the amount of mineralization ranged 518 mg/l (summer-autumn low-level) to 573 mg/l (winter low-water level). A similar pattern was also observed for the seasonal course of the concentrations of individual major ions in the water of the Western Bug (Table 1).

The values of the concentrations of the main ions and the mineralization in the water of tributaries in different seasons are close to these characteristics in the water of the Western Bug. An exception is the relatively high mineralization of the river Poltva, which in the drain in Lviv reaches 784-871 mg/l, reducing in the mouth of the river (in the city of Busk) to 613-670 mg/l.

The ionic composition of theriver waters of the basin is genetically associated with poorly soluble carbonate rocks that lie on its drainage basin.

Table 1. Average Seasonal Concentrations of Main Ions and Water Salinity Value.The Western Bug and its tributaries, mg/l

TheMainriver /tributaries	**HCO_3^-**	**SO_4^{2-}**	**Cl^-**	**Ca^{2+}**	**Mg^{2+}**	**Na^+**	**K^+**	**Total mineralization**
				Spring Flood				
The Western Bug River	275	50	50	88	13	20	3.0	497
Poltva – Lviv	330	120	131	140	18	40	5.0	784
Poltva – Buskcity	302	102	74.8	107	24.1	25.7	3.7	640
Rata	231	37.9	33.6	82.2	9.5	17.7	2.5	414
Solokiya	248	31.1	34.6	85.7	10.5	9.9	1.4	421
Luha	298	30.1	20.1	83.2	10.9	37.6	5.5	487
				Summer-autumn low-water period				
The Western Bug River	288	54	50	92	15	30	4	518
Poltva – Lviv	358	104	110	124	15	80	11	801
Poltva – Buskcity	304	75.8	64.6	110	18.9	32.4	4.6	613
Rata	248	37.8	32	84.1	10.1	18.1	2.5	433
Solokiya	256	43.2	40.0	88.1	10.0	15.2	2.1	455
Luha	306	29.3	18.1	81.9	11.4	32.5	4.8	484
				Winter low-water period				
The Western Bug River	303	64	57	104	17	35	5	573
Poltva – Lviv	347	187	137	134	23	38	5.0	871
Poltva – Buskcity	331	100	92	107	23.2	14,3	2.1	670
Rata	277	32	33.3	88.8	9.3	30.7	4.3	476
Solokiya	265	33.3	37.2	94.6	8.8	21.1	3.0	463
Luha	322	29.8	17.1	84.2	14.1	34.1	4.7	508

Accordingly, in all seasons of the year, HCO_3^- and Ca^{2+} ions predominate in the water. The waters of the Western Bug basin belong to the hydrocarbonate class of the II type calcium group - C_{II}^{Ca}. The contribution of individual ions is as follows: for anions: HCO_3^- (63-64% -eq.) > Cl^- (21-22% -eq.) > SO_4^{2-} (15-16% -eq); for cations: Ca^{2+} (63-66% -eq) > Na^+ + K^+ (16-21% -eq) > Mg^{2+} (15-18% -eq).

The performed correlation analysis of the series of mean annual concentrations of the main ions and the mineralization values with water flow the Western Bug (Kamianka-Buzka) for the period 1971-2015 revealed the presence of biological feedback between the content of all the main ions and the mineralization of the water, on the one hand, and discharge of water on the other. The close relationship was characterized by the correlation coefficient r = 0.73. This indicates the effect of the hydrolicity(ratio of the average discharge over the entire reference period) on the content of the main ions in the water of the river in a multi-year aspect.

For the studied period (1971–2015), periods with average water content and also low-water and high-water periods were noticeable. A comparative analysis of the values of the water indicators of the Western Bug in 7 drains located directly on the river revealed that the maximum concentrations occurred in low-water periods, and the minimum values in high-water periods. However, the local influence of the settlements on the chemical composition of the water of the Western Bug was also significant, manifesting through increases in the concentrations of certain main ions (SO_4^{2-}, Cl^-) and the mineralization of water in insignificant sections of the river located below the cities. Consequently, the results of studies of the hydrochemical regime of the Western Bug and its tributaries, both in the intra-annual and long-term aspects, attested to the determining role of natural factors in the formation of the contents of the main ions. The exception was the Poltva, for which, as it was mentioned above, the significant anthropogenic influence of Lviv is characteristic.

Among the studied biogenic substances, a clear seasonal distribution of concentrations was found only for nitrogen of nitrate and silicon (Table 2).

The lowest concentrations of $N–NO_3^-$ (0.39 mg/l) were observed inthe summer during the vegetation period, when the nitrogen dissolved in water was intensively consumed by hydrobionts. During winter low-water, $N–NO_3^-$ values increased (0.49 mg/l), which is related to the destruction of organic substances and the transition of nitrogen from organic forms to mineral forms following minimal bioaccumulation of nitrates. During the spring flood, the nitrogen concentrations of nitrate nitrogen were reduced due to dilution.

But for the concentrations of biogenic matter (see Table 2), microelements and specific pollutants (Tables 3 and 4), no clear common pattern in their seasonal fluctuations were found, which is related to the significant discreteness of the influence of anthropogenic factors on the formation of their concentrations.

Table 2. Average Seasonal Concentrations of biogenic matter in the Western Bug and its tributaries, mg/l

The Main river /tributaries	**NH_4^+**	**NO_2^-**	**NO_3^-**	**N_{total}**	**$P_{min.}$**	**P_{total}**	**Si**
SpringFlood							
TheWesternBugRiver	3.26	0.10	0.46	3.83	0.16	0.32	3.7
Poltva – Lviv	14.8	0.15	0.45	15.4	1.17	1.80	7.2
Poltva – Buskcity	6.7	0.12	0.43	7.25	0.44	0.83	4.8
Rata	1.1	0.05	0.53	1.68	0.04	0.08	3.7
Solokiya	1.8	0.11	0.36	2.29	0.06	0.12	4.1
Luha	1.3	0.04	0.35	1.70	0.04	0.11	3.4
Summer-autumn low-water period							
The Western Bug River	3.0	0.1	0.39	3.49	0.20	0.43	4.3
Poltva – Lviv	9.8	0.15	0.47	10.4	0.90	1.69	5.9
Poltva – Buskcity	6.7	0.11	0.42	7.2	0.49	0.81	5.1
Rata	0.9	0.04	0.28	1.22	0.05	0.14	4.4
Solokiya	2.0	0.05	0.32	2.37	0.07	0.20	4.1
Luha	1.1	0.06	0.25	1.4	0.05	0.11	3.6
Winterlow-waterperiod							
TheWesternBugRiver	3.63	0.14	0.49	4.28	0.17	0.35	4.4
Poltva – Lviv	10.6	0.17	1.97	11.6	1.54	0.87	6.0
Poltva – Buskcity	7.8	0.18	0.52	8.5	0.32	0.54	8.0
Rata	1.18	0.07	0.54	1.79	0.05	0.12	4.2
Solokiya	2.16	0.09	0.34	2.6	0.09	0.17	4.6
Luha	1.3	0.16	0.50	2.1	0.09	0.31	4.3

Table 3. Average seasonal concentrations of microelements in the water of the Western Bug and its tributaries

The Main river /tributaries	Fe, mg/l	Cu, mcg/l	Zn, mcg/l	Mn, mcg/l
SpringFlood				
TheWesternBugRiver	0.29	19.3	57.5	92.7
Poltva – Lviv	0.48	60.3	160	161
Poltva – Buskcity	0.13	84.6	129	150
Rata	0.23	6.0	28.7	78
Solokiya	0.19	7.4	6.1	77
Luha	0.49	24.5	38.5	94
Summer-autumn low-water period				
The Western BugRiver	0.25	13.8	45.1	58.5
Poltva – Lviv	1.33	24	43.5	166
Poltva – Buskcity	0.61	16	64.8	158
Rata	0.29	3.4	11.6	76
Solokiya	0.29	8.0	11.3	78
Luha	0.51	9.8	58.1	89.2
Winter low-water period				
TheWesternBugRiver	0.14	11.8	43.2	35.6
Poltva – Lviv	0.47	6.3	2.4	158
Poltva – Buskcity	0.62	62	93	144
Rata	0.24	4.1	14.1	75
Solokiya	0.22	8.4	16.5	73
Luha	0.43	18	36.1	71.1

Table 4. Average seasonal concentrations of specific pollutants in the water of the Western Bug and its tributaries, mg/l

The Main river /tributaries	SPAR	Phenols	Petroleumproducts
SpringFlood			
TheWesternBugRiver	0.07	0.005	0.15
Poltva – Lviv	0.68	0.032	0.63
Poltva – Buskcity	0.35	0.011	0.44
Rata	0.05	0.002	0.75
Solokiya	0.04	0.002	0.04
Luha	0.05	0.004	0.24
Summer-autumn low-water period			
The Western Bug River	0.05	0.004	0.10
Poltva – Lviv	0.01	0.033	0.27
Poltva – Buskcity	0.10	0.003	0.13
Rata	0.04	0.010	0.11
Solokiya	0.03	0.001	0.06
Luha	0.03	0.004	0.09
Winter low-water period			
The Western Bug River	0.07	0.003	0.09
Poltva – Lviv	0.15	0.011	0.34
Poltva – Buskcity	0.11	0.004	0.18
Rata	0.08	0.001	0.06
Solokiya	0.02	0.001	0.05
Luha	0.04	0.001	0.09

During all the seasons, significant occasional exceedances of TLV (threshold limit value) for biogenic matter, microelements and specific pollutants in water bodies for fishery use were determined in the water of the Poltva and in some cases in the Western Bug along the section from the city of Busk to the town of Kamianka-Buzka. This occurred due to the influence of water of the Poltva, which is polluted with these components. For some of these, these excesses remain at the averaged values (Fe, Zn, Mn).

Runoff of chemical elements. The study on the removal of dissolved chemicals with the waters of the Western Bug from the territory of Ukraine is particularly important and relevant in the light of the stricter requirements of the European Union (EU) regarding the transfer of pollutants from the territory of neighboring countries. As the previous studies indicated, the characteristics of the removal of chemicals with river waters can be an indicator of anthropogenic impact on the chemical composition of river waters (Zakrevskii et al., 1988; Khil'chevskii, Chebot'ko, 1994).

The ion runoff (R_i) in a certain drain is calculated by the formula (Khilchevskyi, Osadchyi, Kurylo, 2012):

$R_i = W \cdot C$, thousands of tons (for a season, for a year), (1)

where W – volume of runoff flow, thousand m^3; C –concentration of the ion (or the sum of the ions), mg/l.

The volume of water runoff W is calculated as follows:

$$W = Q \cdot t \qquad (2)$$

where Q – water discharge, m^3/s; t – time (season, year).

No problems occur with average concentrations of chemical components in the water of the Western Bug. But how is it possible to determine water discharges by the closing drain in the Ukrainian part of the catchment area of the Western Bug, which in reality does not exist in the hydrological monitoring system?

For the calculations, a conditional hydrological drain "Border-3." was chosen on the Western Bug. Borders of three states cross here - Ukraine, Poland and Belarus, which is the closing drain in the Ukrainian part of the basin. For this conditional hydrological drain, we provided the characteristics of water discharge and water runoff volumes obtained through the runoff modules (Table 5). These data were used to calculate the runoff of chemicals.

Table 5. Average volume of water drain (W) of the Western Bug in the conventional drain "Border-3" (crossing of the borders of Ukraine, Poland and Belarus), the last in the Ukrainian part of the basin, million m^3/year

Characteristic	Spring Flood	Summer-autumnlow-waterperiod	Winterlow-waterperiod	In a year
W - from the territory of Ukraine	918	382	229	1529*
W - from the territory of Ukraine and Poland	990	413	248	1651**

*Note: * - the average annual water discharge (Q) in the conventional drain "Border-3", which is formed from the catchment area of the Western Bug in Ukraine, is 48.5 m^3/s; ** - in the territory of Ukraine and Poland - 52.3 m^3/s.*

The average annual ion runoff of the Western Bug from the territory of Ukraine is 793.5 thousand tons (78.3 tons/km^2); from the territory of Ukraine and Poland – 857,0 thousand tons (Table 6). As we can see, in this part of the river, 93% of ion runoff is taken from the territory of Ukraine and 7% from the territory of Poland (Fig. 2).

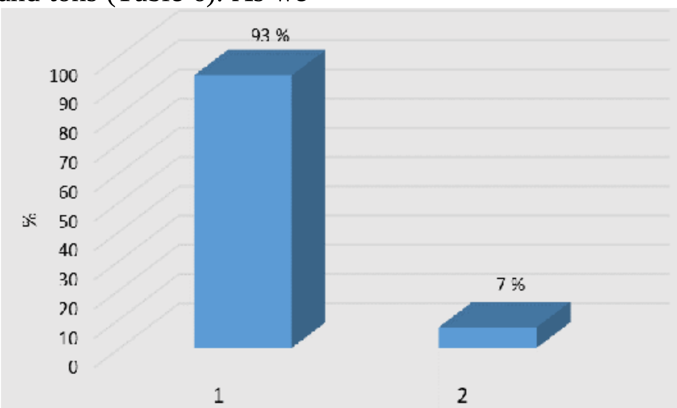

Fig. 2. Mean annual ion flow of the Western Bug from the territory of Ukraine (1) and from the territory of Poland (2) in the conventional drain "Border-3", the last in the Ukrainian part of the basin,%

Table 6. Average annual and average seasonal ion runoff of the Western Bug river from the territory of Ukraine (above the line – thousand tons, below the line – t/km^2)

Season / Year	HCO_3^-	SO_4^{2-}	Cl^-	Ca^{2+}	Mg^{2+}	Na^+	K^+	The sum of ions
Spring Flood	250.6 (23.2)	45.8 (4.2)	47.4 (4.4)	82.3 (7.6)	11.6 (1.0)	17.8 (1.6)	2.5 (0.2)	458 (42.4)
Summer-autumnlow-waterperiod	108.1 (10)	19.7 1.8	20.4 (1.9)	35.3 (3.3)	5.9 (0.5)	11.3 (1.0)	1.6 (0.1)	202.5 (18.8)
Winterlow-waterperiod	68.7 (6.4)	13.7 (1.3)	13.5 (1.2)	24.0 (2.2)	3.9 (0.4)	8.0 (0.7)	1.1 (0.1)	133 (12.3)
In a year	427.4 (39.6)	79.2 (7.3)	81.3 (7.5)	141.6 (13.1)	21.4 (1.9)	37.1 (3.3)	5.2 (0.5)	793.5 (73.5)

In Table. 7shows the data for the runoff of biogenic matter, Table. 8 – runoff of microelements with the waters of the Western Bug from the territory of Ukraine.

Table 7. Average annual and average seasonal runoff of biogenic matter with waters of the Western Bug from the territory of Ukraine (above the line – thousand tons, under the line – t/km^2)

Season / Year	NH_4^+	NO_2^-	NO_3^-	N_{total}	$P_{min.}$	P_{total}	Si
Spring Flood	3.0 0.27	0.092 0.008	0.4 0.037	3.5 0.32	0.1 0.009	-	3.4 0.31
Summer-autumn low-water period	1.1 0.1	0.037 0.003	0.1 0.009	1.3 0.12	0.074 0.007	-	1.6 0.15
Winter low-water period	0.8 0.074	0.031 0.003	0.1 0.009	0.9 0.08	0.038 0.003	-	1.0 0.09
Over the year	4.9 0.45	0.16 0.014	0.6 0.055	5.7 0.52	0.212 0.019	-	6.0 0.55

Table 8. Average annual and average seasonal runoff of microelements with waters of the Western Bug from the territory of Ukraine (by Fe: above the line – thousand tons, under the line – t/km^2, by Cu, Zn, Mn: above the line – thousand kg, under the line – kg/km^2)

Season / Year	Fe	Cu	Zn	Mn
Spring Flood	0.3 0.28	17.7 1.6	22.0 2.0	85.0 7.9
Summer-autumn low-water period	0.095 0.009	5.3 0.5	17.2 1.6	22.3 2.0
Winter low-water period	0.032 0.003	2.7 0.3	9.9 0.9	8.1 0.7
Over the year	0.42 0.039	25.7 2.4	49.1 4.5	115.4 10.6

The runoff of different groups of chemical components that are carried out with the waters of the Western Bug is distributed by seasons as follows. The main ions: spring high water – 48-59%; summer-autumn low-water period – 25-31%; winter low-water – 16-22%. Biogenic matter: spring high water – 47-67%; summer-autumn low-water period – 17-35%; winter low-water – 16-19%. Heavy metals: spring high water – 45-74%; summer-autumn low – 19-35%; winter low-water – 6-20%.

Considering the specific nature of the chemical composition of the Poltva, we studied the contribution of this river to the formation of the main ion and biogenic matter runoff in the upper part of the Western Bug (right after the confluence of the PoltvaatKamianka-Buzka) and in the lower part of the Western Bug for Ukraine – on the border of Ukraine, Poland and Belarus (Table 9 and 10). The following methodical approach was used. The data calculated for the runoff of the mentioned chemical components, obtained for the mouth of the Poltva (Busk), were compared with the data for two drains on the Western Bug: 1) the Western Bug – Kamianka-Buzka, below the confluence of Poltva (upper); 2) the Western Bug is the conventional drain "Border-3", the closing drain in the Ukrainian part of the basin (the lower one).

Table 9. Contribution of the Poltva to the water (W) and ionic runoff of the Western Bug, calculated for two drains: 1) the Western Bug – Kamianka-Buzka, below the confluence of Poltva (upper); 2) the Western Bug is the conventional drain "Border-3", the closing drain the Ukrainian part of the basin (lower),%

River, Drain	**W**	**HCO_3^-**	**SO_4^{2-}**	**Cl^-**	**Ca^{2+}**	**Mg^{2+}**	**Na^++K^+**	**The sum of ions**
Western Bug – Kamianka-Buzka (upper drain)	58	59	98	76	66	87	60	66
The Western Bug – the conventional drain "Border-3" (lower drain)	23	25	38	33	27	37	25	28

Table 10. Contribution of the Poltva to the biogenic runoff of the river Western Bug, calculated for two drains: 1) the Western Bug – Kamianka-Buzka, below the confluence of the Poltva (upper); 2) the Western Bug is the conventional drain "Border-3", the closing drain in the Ukrainian part of the basin (lower),%

Drain in the Western Bug	**NH_4^+**	**NO_2^-**	**NO_3^-**	**N_{total}**	**$P_{min.}$**	**Si**
Western Bug - Kamianka-Buzka (Upper drain)	70	66	51	68	80	67
The Western Bug is the conventional border "Border-3" (Lower drain)	47	28	23	44	71	30

As can be seen from Table. 9 ("Upper drain"), the share of the water runoff of the Poltva River at the place where it flows into in the Western Bug is 58% of the water runoff of the main river. At the same time, the share of the total ion runoff of the Poltva River is higher – up to 66% (Fig. 3). The share of the runoff of some main ions reaches: 76% (Cl^-), 87% (Mg^{2+}) and 98% (SO_4^{2-}). For total nitrogen, this figure equals 68%, for phosphates – up to 80% (see Table 10).

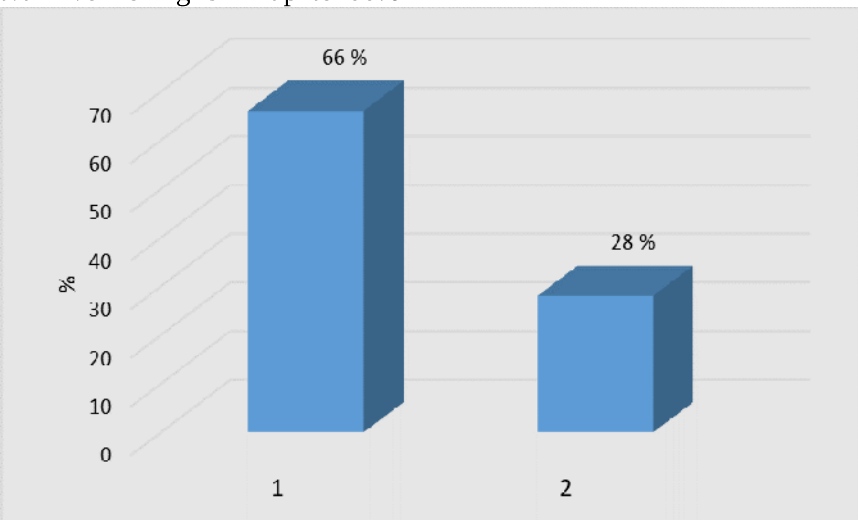

Fig. 3. Contribution of the Poltva in the ionic runoff of the Western Bug, calculated for two drains:1) the Western Bug – Kamianka-Buzka, below the confluence of Poltva (upper); 2) the Western Bug – the conventional drain "Border-3", the closing drain the Ukrainian part of the basin (lower),%

In the balance of runoff in the closing drain in the Ukrainian part of the Western Bug Basin ("lower drain" in Tables 9 and 10), the Poltva's influence is less evident. There, the share of the Poltva's water fun off decreases to 23%. Although the share of the total ion runoff of the Poltava is still somewhat higher – 28%, and the share of runoff of some main ions, anthropogenic impact indicators, reaches: 33% (Cl^-), 37% (Mg^{2+}) and 38% (SO_4^{2-}). For total nitrogen, this indicator was 44%, for phosphates – up to 71% (see Table 10).

Thus, the comparative methodological approach allowed determining a significant influence of the Poltva on the formation of the chemical composition of the Western Bug, especially in its upper part.

Conclusions

1. The hydrographic network of the Western Bug basin on the territory of Ukraine has 2,044 rivers.
2. The classification of the rivers of the Western Bug basin by catchment area, performed in accordance with the requirements of the EU WFD, showed the following results: in this basin within Ukraine there is one very large river, (actually this is the West Bug itself), and also three large rivers – the Poltva, Rata and Luha. There are also 30 medium and 2,010 small rivers (among which 1,966 rivers are less than 10 km).
3. The data obtained and the revealed regularities allowed us to determine the leading role of natural fac-tors in the formation of the hydrocarbonate-calcium ion composition of the river waters of the Western Bug basin. The content of the main ions and the salinity of the river waters are distinguished by a sufficiently clear seasonal character: a decrease in the spring flood and an increase in the low water level (mineralization of the water of the Western Bug – 497-573 mg/l).
4. Mineralization of the Poltva River (the left tributary of the Western Bug), located in the same natural conditions, is significantly different. So, in the area of the city of Lviv (the upper area of the Poltva River), it reaches 784-871 mg/l, and at the mouth of the river (in the city of Busk, at the confluence of the Western Bug) 613-670 mg/l. In this case, the chemical type of water begins to affect sulfates and chlorides. This situation is explained by the discharge of sewage from the city of Lviv into the Poltva River.
5. At the same time, studies of the regime of nutrients, microelements, and specific pollutants in the water of the Western Bug did not find common regularities in their seasonal variations, which is related to the significant discreteness of the influence of anthropogenic factors on the formation of their concentrations.
6. The methodological approach used to calculate the flow of dissolved chemicals allowed us to estimate the balance of substances, both natural and anthropogenic, that are taken out with the waters of the Western Bug from the territory of Ukraine (93%), as well as from the territory of Poland (7%) to the border with Belarus.
7. The comparative methodological approach allowed us to quantify the significant influence of the Poltva River on the formation of the chemical composition of the water of the Western Bug, especially in its upper part. The share of Poltva's water flow within the Western Bug is 58% of its water flow. At the same time, the share of the total ion flow is higher – 66%. The share of the discharge of individual principal ions reaches: 76% (Cl^-), 87% (Mg^{2+}) and 98% (SO_4^{2-}). For nitrogen, this figure is 68%, for phosphates – up to 80%.

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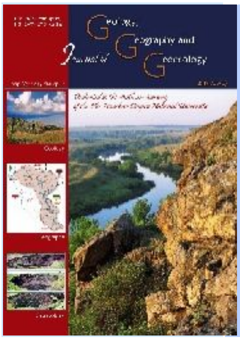

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On the development of geotouristic routes on the objects of the Precambrian Rock Association of the Western Priazovia

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Abstract. The article describes the priorities of the development of a new sphere in tourism – the geological sphere (geotourism). We have developed a complex of necessary measures for increasing the touristic attractiveness of objects of the geological heritage including justification of the touristic value of the objects selected for creating the touristic routes, posting information about the objects on available web-sites, including not only geotouristic routes and objects in the surrounding area, but also any other tourist attractions: geobotanical, landscape, archeological, historical-cultural, sacral, ethnic, etc. The paper justifies the necessity of involving the outcrop of Precambrian rocks of crystalline basement as geotouristic objects of Western Pryazovia. It was determined that almost all the most attractive geotouristic objects are geological relics of nature or geosites, some of which have official status and are included in the Nature-Reserve Lands of Ukraine. The paper describes the most important pages of the ancient history of Pryazovia in general and the Berda river in particular. Three variants of routes have been proposed, each based on the observations of the authors and their colleagues during geological surveys and field geological practice with university students specializing in geology. It was found that the most promising objects for touristic routes are the outcrops of crystalline Precambrian rocks located along the Berda river and surrounding territories. There, one can see a practically full section of outcrops of rock associations of the Osypenkivska Archean seria, which compose the Olzhinska metabasite and Krutobalkivska metasedimental suites; intrusive and ultrametamorphic formations which form the Osypenkivskyi gabbro-diorite, the Shevchenkivskyi plagiogranite-tonalite and the Saltychanskyi granite complexes. Among the geological objects which are exposed to observation in this relatively small territory, there are deposits of gold (Surozhske), rare metals (Kruta Balka), ceramical pegmatite (Mohyla Zelena and Velykyi Tabir Ravinne), iron (Korsak Mohyla). These objects give us a full impression of the structure of the crystalline massif of the Western Pryazovia megastructure of the Ukrainian shield. We have formulated the main recommendations for the preparation and conducting of geotourism routes in Ukraine,which can be the basis for development of both internal and external geotourism.

Key words: geotourism, Precambrian, geological site, geosite, intrusive complexes, ultrametamorphic complexes, Western Azov Sea, Ukrainian shield.

До питання розробки геотуристичних маршрутів по об’єктах докембрійського фундаменту Західного Приазов’я

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Анотація. Розглянуто пріоритетність розвитку нового напрямку в туризмі - геологічного (геотуризму). Розроблено комплекс необхідних заходів для підвищення туристичної привабливості об’єктів геологічної спадщини, серед яких розробка обґрунтування туристичної цінності вибраного для проведення геологічних маршрутів об’єкту, розміщення в інтернет-ресурсах інформації про об’єкт на легкодоступному сайті, включення до маршруту не тільки довколишніх геотуристичних маршрутів і об’єктів, але й будь-яких туристичних атракцій: геоботанічних, ландшафтних, археологічних, історико-культурних, сакральних, етнічних та інше. Обґрунтовано необхідність для Західного Приазов’я залучати у якості геотуристичних об’єктів саме вихід порід докембрійського кристалічного фундаменту. Визначено, що практично всі найбільш привабливі об’єкти геотуризму являють собою геологічні пам’ятки природи або геосайти, частина з яких має офіційний природоохоронний статус і входить до Природно-заповідного фонду України. Наведено важливі сторінки давньої історії Приазов'я в цілому та р. Берди зокрема. Пропонується три варіанти маршрутів, кожен з яких спирається на дослідження авторів та їх колег при проведенні геолого-знімальних робіт та польових навчальних геологічних практик із студентами університетів, що навчаються за напрямом геологія. Установлено, що найбільш перспективними для проведення туристичних маршрутів є відслонення кристалічних порід докембрію вздовж річки Берда і на прилеглих до неї територіях. Тут практично у повному розрізі відслонюються породні асоціації осипенківської серії архею, що складають ольжинську метабазитову і крутобалківську метаосадову світи; інтрузивні і ультраметаморфічні утворення, що складають осипенківський габро-діоритовий, шеченківський плагіограніт-тоналітовий і салтичанський гранітний комплекси. На означеній незначній за площею території розміщуються і доступні для безпосереднього спостереження родовища золота (Сурожське), рідкісних металів (Крута Балка), керамічних пегматитів (Могила Зелена і Балка Великого Табору), заліза (Корсак Могила). Ці об'єкти нададуть повне уявлення про будову кристалічного масиву Західноприазовської мегаструктури Українського щита. Сформульовані основні рекомендації по підготовці і проведенню геотуристичних маршрутів в Україні. Запропоновані і описані найбільш важливі геологічні об'єкти Західного Приазов'я, використання яких може стати основою для розвитку як внутрішнього так і зовнішнього геотуризму.

Ключові слова: геотуризм, докембрій, геологічна пам'ятка, геосайт, інтрузивні комплекси, ультраметаморфічні комплекси, Західне Приазов'я, Український щит.

Introduction. Geological tourism being a developing global trend takes an important place among tours, and to some extent can meet the needs of the most demanding tourists. This type of tourism is new for Ukraine, but not for the world. Internet offers a plenty of links to various geological, paleontological and mineralogical tours and excursions around different geological places of interest and gems and mineral deposits. Ukraine can also add to the list of links, as it is rich in surface geological objects in a number of natural and artificial outcrops aged from the Old Archean (dating back more than 3.4 bn years) to quaternary deposits with a complete geological section rich in various rock types, minerals, and skeletal remnants of fauna. It is necessary only to develop the most interesting routes and create adequate conditions for observation of these geological objects along these routes.

It is clear that for a geological object to become a touristic one, it has to be adequately prepared. According to available Internet resources, it is necessary:

1. To develop the substantiation of touristic attractiveness of the chosen geological routes. To give characteristics of the surrounding landscape.

2. To give short geological insight into geological structure of Ukraine in general and by region of the touristic object, in particular. To give short characteristics of surrounding geotouristic routes and objects.

3. To give detailed geological description of the object or the route, to train guides.

4. To prepare the object for excursions (to clear the rock outcrops, to plot a route with route identifiers, the main and intermediate information stands in two languages about the geological object in general and each main outcrop in particular, to prepare appropriate tools, samples for demonstration and probably, for sale for tourists).

5. To design brochures with the description of the route or geological object, maps and schemes to provide or sell to tourists. The brochure must contain general information (how to get to the object, accommodations available). That is, information must be sufficient for the tourists to orient themselves around the object.

6. To upload information to the Internet about the object in some easily available web-site.

Western Pryazovia is unique for geotourism. It encompasses crystalline massif of the same name megastructure of the Ukrainian Shield (USh), mainly containing thin quaternary deposits, which resulted in the formation of significant visible crystalline rocks outcrops even in shallow river trenches. The outcrops are sometimes continuous or with insignificant turfness: for hundreds of meters, or even first kilometers one can observe various crystalline rock complexes formed within1.4bn years from 3.4 to 2.0bn years.

Gneiss-migmatite-plagiogranite complexes of Early Archean, gneiss-shale metamorphites and intrusive formations of ultramafic, intermediate and acid composition of Middle and Late Archean are available for observation. Granite complexes dating back to Early Proterozoic period are especially diverse. At this, we have an opportunity to observe metamorphic complexes of different level of facial changes – from granulite to greenschist facies. It should also be noted, that there is a possibility of immediate observation of granite pegmatites in natural and artificial outcrops. These unique geological formations are both geological natural objects and minerals, depending on the composition of pegmatite, on ceramic raw materials and rare (lithium, rubidium, cesium, tantalum, niobium, tin, beryllium) and rare earths elements of yttrium group. There is also a rare opportunity to observe rocks of Surozski gold deposit in natural outcrops, ravines and adits.

Below is given a short characteristic of the most attractive geological objects that, from the authors' our point of view deserve to become geotouristic objects.

Substantiation of touristic attractiveness of geological route along the Berda river. The picturesque steppe river Berda has its sources in the

Pryazovia hill ridges, flows through Bilmaksk and Berdiansk districts of Zaporizhia oblast, crosses a small area of Donetsk oblast and flows into the Azov Sea. The old names of the river are Hipakiris, Agara, Agarlibert, Kayala, Kayalibert (Berda (river), 2018). The Turkic name "Berda" means "Given by God". According to our data, berdo means "cliff" (Yanko, 1973). It is presumed that initially the name meant "the river that flows through cliff banks" (Dolgachev, 1989). At any rate, the river bordered by rocky cliffs of crystalline rocks lives up to this presumption. Presumably, in the ancient times, nomads came across a steppe river rich in prey, juicy grass and fish. It is possible that some of them gave this name to the area, and then to the river flowing there. It is likely that Persian king Darius in the summer of 515-512 BC led his innumerous army to “Stone graves of Scythian kings” located on the right bank of the Karatush river, to the Berda river (Azovskoe kazache vojsko, 2018). Before 1770 the banks of the Berda river (Kaiala-Bert, Stony Berda, Great Berda) were the border lines between the countries of Western Nogai (Crimean Steppe – Ogula desert) of the Crimean khanate and the lands of Kalmiusk area of Zaporizhzhia state. For the first time, the Berda river is mentioned in Zaporizhzhian Cossacks’ chronicles in 1575-1576, when Bohdan Mykhailovych Ruzhunsky (? – 1576). Volyn prince, Zaporizhzhia Cossack hetman who was the first hetman acknowledged by Polish authorities, led a military campaign across the Berda river. Starting from this time, the banks of this Pryazovian river from its riverhead to its mouth belonged to Zhaporizhzhia area. In the autumn of 1616 Petro Konashevych-Sahaidachny, "The Hetman of both banks of the Dnipro and the Zaporozhian Cossacks", sailed via the Dnipro to the Black Sea on Chaikas (big boats) with a group of two thousand cossacks, approached the eastern shore of Taurica (the Crimea), where he burned down a trading city Kafa (where currently is Feodosia), and then, after crossing the Black Sea to the south, approached the coasts of Anatolia, where he stormed the Turkish Black Sea ports Trebizond, Sinope, subjected the environs of Stambul to fire and sword, and returned to the Sich via the Kerch Strait, the Azov Sea, the Berda and the Konka (Konka waters) (Azovskoe kazache vojsko, 2018). In the area of the Kalaitanivka village of Berdiansk district of Zaporizhia oblast, the remains of the Zaharivska Fortress can still be seen today. Since that time, the shores of the Pryazovia River Berda from its source to the mouth became property of the Zaporizhians. Along the Berda and Konka in the 1770s , the Dnipro defence line was built, which consisted of seven fortresses located 30 versts one from another: Oleksandrivska, Mykytynska (Velyky Luh floodplain), Hryhorivska, Kyrylivska, Oleksiivska, Zaharivska and Saint Peter (Petrovska, Berdianska) fortresses. The mouth of the river is located in the vicinity of Druga Vershina village (Kuibyshevski region of Zaporizhzhia oblast) on the slopes of Pryazovia hills at the height of 300m above the sea level next to Mohyla Kordonska burial mound. It flows along the territory of Kuibyshev and Berdiansk regions of Zaporizhzhia oblast. The river flows along steppe area. Its banks are characterized by steppe and meadow flora with occasional artificial forest plantations. Sometimes crystalline rocks outcrops can be seen along the river banks (Fig.1).

Fig. 1 Outcrop of crystalline rocks on the right bank of the Berda river

In the interstream area between rivers Berdda and Kalchyk (tributary of the river Kalmius), and along the right bank of the small river Karatysh (left tributary of the Berda river) there is located a natural re-serve "Kamiani Mohyly", a subsidiary of Ukrainian steppe natural reserve. In the mid-stream of the river, bordering with Donetsk oblast, is located regional landscape park "Polovetska step". On the Berda river, near Osypenko village, in 1954 was build Berdianske water basin. The water from the basin is used to irrigate and supply water to seven adjacent settlements, including the town of Berdiansk. The range of fish in the river is wide: redfin, crucian carp, pike. 25 km from the mouth, river-valley significantly increases. The floodplain is one-sided up to 100m wide. In the lower areas it is swamped. River fall is 2.1 m/km. The stream is fast. The channel is twisting, 6-10m wide with sparse inundation up to 15-25m. The channel is grassed by a quarter. The floor is sandy, and stony on cripples. It freezes in December, and unfreezes in early March. The ices is unstable. The river is nourished from the show and ground waters. Spring floods are characteristics. It intakes melt-water even in winter during thaw, which results in the increase of the water-level. It doesn't run dry. It flows into the Azov Sea near Novopetrivka vil. (Berdiansk regiona, Zaporizhzhia oblast). Berdianska sand bar exists thanks to the Berda river. The river length is 125 km.

Description of the main geological objects. The objects that outcrop along the Berda river and its confluents are offered for geological tours, and belong to Western Pryazovia megastructure of the Pryazovian megablock of the Ukrainian Shield. Western Pryazovia megastructure is structurally and historically the oldest plume-structure of the Ukrainian Shield (Early-Mid-Archean). It consists of Vovchansk and Saltychansk granite-gneiss domes and Orihovo-Pavlogradski and Maloyenisolski synclinores located around (Bobrov, Sivoronov, Malyuk and Lisenko, 2002; Isakov, Bobrov, Paranko, Shpilchak & Shurko, 2011; Isakov & Paranko, 2013) (Fig. 2).

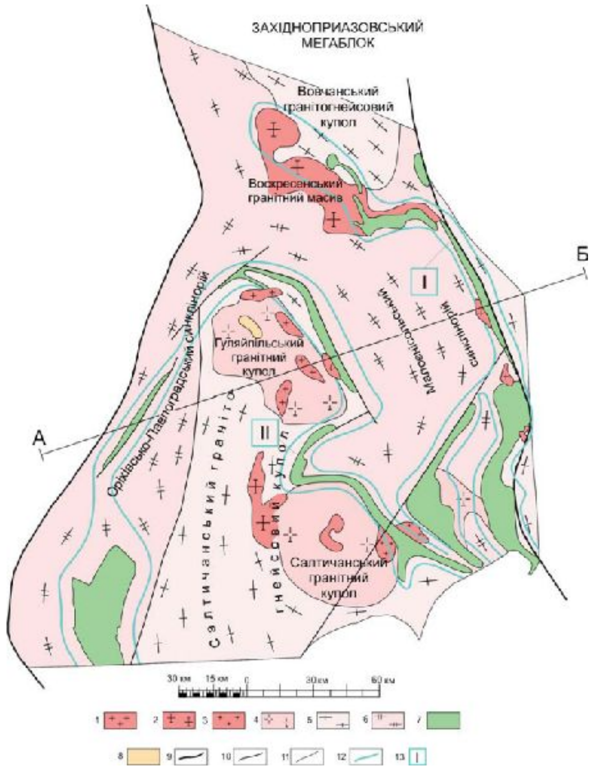

Fig. 2. Geological-structural scheme of Western Pryazovia megablock.
Twofeldspar granites of: 1 – Dobropilsky, 2 – Yanvarsky, 3 – Saltychansky complexes; 4 – plagiogranites, tonalites of Shevchenkivsky complex; 5 - metamorphic Western Pryazovia series and ultrametamorphic Novopavlivsky complex of dome structures; 6 – megamorphic rock masses (Vovchanska and Dragunska) and ultrametamorphic Remivsky complex of suture area; 7 – megamorphized volcanogenic-terrigenic complexes of trough structures of greenstone type (Osypenkivska series and Novogurivska, Ternuvatska, Kosivtsevska rock masses); 8 – terrigenic complexes of fault-line superimposed structure (Guliaipilska suite); 9 – regional abyssal fractures; 10 – other disjunctive dislocations; 11 – geological boundaries; 12 – conventional boundaries of greenstone belts; 13 – greenstone belts: I – Shevchenkivsko-Berestivsky, II – Sorokynsko-Gaichursky

The domes are composed of ul-trametamorphised gneisses and crystalline schist of Western Pryazovia series of the Early Archean, while its central parts are filled with granitoid formations of Mid-Late Archean and Early Proterozoic era. Synclinores are presented by highly-metamorphized metamorphites jammed into narrow linear isocline folds of Vovchanska and Dragunska rock mass of the Early Archean. In the outline of the domes there are developed specific long narrow trough structures (up to 40km long, mainly 1-2km wide), composed of metavolcanogenic and metaterrigenic formations of different age of green-stone complexes of Mid- and Late Archean.Trough structures form two discrete arch-like belts. South-Western Sorokinsko-Gaichurski belt stretches to more than 300 km and enframes Saltychansky granite-gneiss dome practically along the perimeter in the form of discrete trough structures. North-Eastern Shevchenkivsko-Berestivski belt enframes marginal Eastern and Northern parts of the megablock.

Intrusive magmatic formations of Western Pryazovia megastructure are presented by massifs of Shevchenkivsky plagiogranites of granite magmatic domes such as Yelyseivsky and Guliaipilsky, as well as multiple phase intrusives of Yanvarsky, Dogropilsky and Saltychansky complexes developed along greenstone trough structures (Isakov, Bobrov, Paranko, Shpilchak & Shurko, 2011; Isakov & Paranko, 2013). The establishing of granite domes and massifs resulted in the formation of the basement structures of the level and led to the formation of greenstone troughs(State geological map of Ukraine. Scale 1: 200,000. Series: Central-Ukrainian. Sheets L-37-VIII (Mariupol), L-37-IX (Taganrog).

Object under observation 1. Section of greenstone complex of Sorokinsky structure on the right bank of the Berda river. The route goes across Surozhska area of Sorokinska greenstone structure (GS) (Geology, Radiological Age, Metallogeny of Greenstone Complexes in the Ukrainian Shield, 2008) (Fig. 3). The length of the route is 1.36km. Here in natural outcrops, one can observe in details a practically uninterrupted section of Olzhynska and Krutobalkivska suites of Osypenkivska series dating to Mid- and Late Archean, presented by rock complexes of metacomatiit-tholeiite, metarhyodacite and metaconglomerate-sandstone-clay-schist formations composing Sorokinska structure, metamorphised into greenschist, epidote-amphibolite and amphibolite levels of metamorphism.

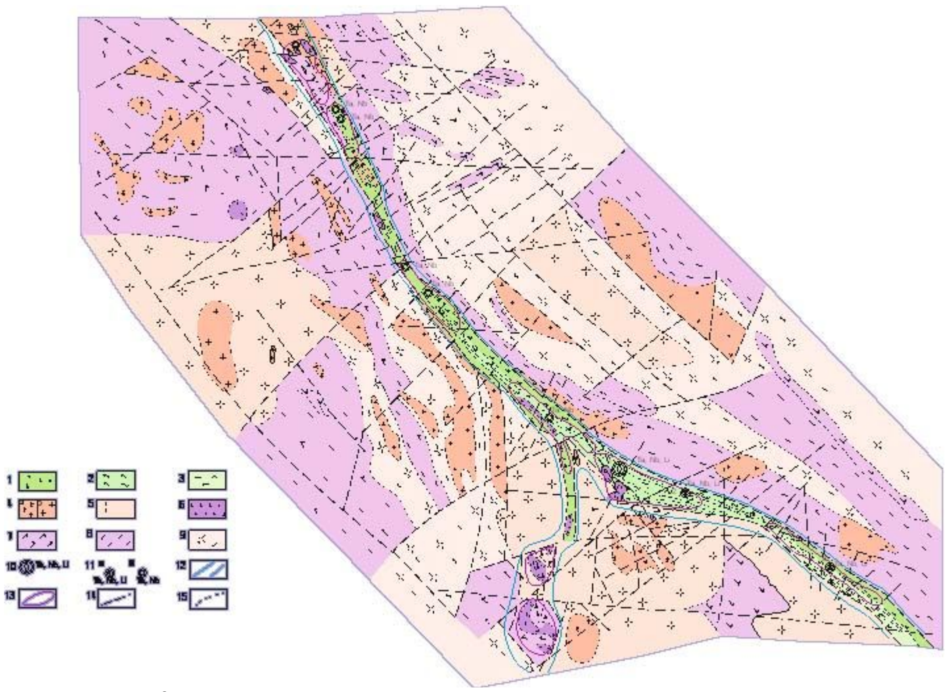

Fig.3 Schematic geological map of Sorokynska greenstone structure:
1 – megavolcanites of Olzhynska suite; 2 – mica-ceous schists of Krutobalkivska suite; 3 – terrigenic-homogenic formations of Sadova suite; 4 – granites: a – muscovite and muscovite-biotite granites of Yanvarsky complex; b – orthite-bearing granites of Saltychanski complex; 5 – plagiogranites of Shevchankivsky complex; 6 – ultrabasite bodies; 7 – amphibole-pyroxene gneisses and schists of Western Pryazovia series; 8 – biotite gneisses of Dragunska rock mass; 9 – plagiomigmatites; 10 – Kruta Balka rare metals deposit; 11 – associated with pegmatites: a – ore occurrence, b – anomalies of rare metals; 12 – development outline of Sorokynske pegmatite field; 13 – intersection of rare-metal pegmatites; 14 - disjunctive dislocations; 15 – geological boundaries.

Within Surozka area, there is a sudden change of North-West direction of strike of the main syncline of Sorokinska GS to East-West direction. Its span reaches 2100m. Southern wing tends northward; angle of dip of the rocks is steep up to near-vertical in Southern direction.

At the beginning of the route one can observe outcrops of metabasites of Olzhynska suite. Metabasites are presented by amphibolites along metabasalts and metabasalt tuffs (tuff-lava) as well as metagabbro-dolerites that are comagmatic to them (Fig. 4).

Fig. 4 Amphibolites along metabasalts and metabasalt tuffs (tuff-lava).

Further along the route, there is an outcrop of acid volcanites. The rock mass is presented by metarhyodacites, metarhyolite with porphyritic structure conditioned by the presence of rather large separations of quartz and plagioclase (oligoclase) at the background of fine-cryptograin kalifeldspath-plagioclase-quartz formation of rock mass (0.06-0.15 mm).

Isochronic age, obtained by isotropic U-Pb ratio of zircon (Artemenko, Tatarinova & Popov, 2001)is 3160±140 mln years.

Further along the route, there are observed metabasites followed by outcrops of significant ultra-basite part of section of Olzhynska suite, they are presented by metacomatiit-dunite-harzburgite volcanic-plutonic association. At the interface with terrigenous rock mass, there are observed iron gold-bearing quarzites (Artemenko, Tatarinova & Popov, 2001).

Further on, there are outcrops of metaterrigenous formations of Krutobalkivska suite (Fig. 5) that form nonconformable boundaries with formations of Olzhynska suite and occur in the core part of Sorokinska GS.

Fig. 5. Outcrops of metaterrigenous formations of Krutobalkynska suite

This assize is presented by paragenesis of coarse-terrigenous deposits (metaconglomerates, metagravelites, sandstone) that are associated with quartz-sillimanite-garnet schists and metasandstone-clay formations of high alumina ratio up to high-aluminous types (andalusite-staurolite-cordierit schist). In the section, there are also various schists: garnet-biotite-feldspar-quartz, biotite-feldspar-quartz, bi-nary mica, turmalin-muskovit-biotite-feldspar-quartz, sometimes with graphite, tourmaline; staurolite-garnet-biotite-feldspar-quartz, sillimanite-garnet-biotite-feldspar-quartz and other types of schist with relict blastopsammitic structures. According to Artemenko G.V. at al. (Artemenko, Tatarinova & Popov, 2001) cluster-forming zircon is dated 3330±40 mln. Years U-Pb. Zircon characterizes the radiogenic age of the source of decomposition that provided the fragmentary material to the basin of the sedimentary formations of the time of Kruta Balka.

Object under observation 2. Outcrops of metavolcanogenic section (Olzhynska suite) of greenstone complex of Sorokynska structure on the left bak of the Berda river. This route is a logical continuation of the previous one. Here one can observe in detail petrographic kinds of basite-ultrabasite rock mass of Olzhynska suite (Geology, Radiological Age, Metallogeny of Greenstone Complexes in the Ukrainian Shield, 2008). The length of the route is 1.1km. In ledge rocks up to 20m high and about 150m long, there are observed essentially ultrabasite and basite part of the section of Olzhynska suite. The lower part is presented by ball-pillow-like lavas of metabasalts, the upper part – by tremolitite and actinolitite developed on metacomatiites. In the latter, there are observed relicts of spinifex-structures conditioned by the development of specific needle-like separations of olivine. The section contains plutonic formations – amphibolites that in their turn form subconformable and transverse dyke and vein bodies. In metabasalts, there are diognozed weakly deformed ellipse-like pillows with dimensions 15-50 by 5-23 cm. Peripheral parts of the balls being guarding areas, are characterized by a darker colour and coarse-grain structure (at the expense of post-genesis recrystallization). Balls and pillows of the basalt lavas have distinctive "tailings" in the lower part, which allows determining the direction of lava flow. The above mentioned rocks are cleaved by a series of pegmatite veins with rare-metal specialization.

Further along the route, there are observed active contacts of Shevchenkivsky plagiogranites with metavolcanites of Olzhynska suite.

Object under observation 3. Surozke gold-ore deposit (within Object under observation 1). The excursionists will have a chance to see a cross-section of one of iron quarzites in an adit and in an outcrop (iron quarzites represent a bedrock outcrop (with the thickness about 5m) of a gold-ore body of the Surozke deposit).

Ledge rock crops out on the slope of a hill to the left edge of mouth part of the Sobacha river. The abandoned adit is located nearby. In the mentioned outcrop and adit, gold-bearing magnetite quarzites crop out (Fig. 6), located adjacent to metabasite rocks of Olzhynska suite with metaterrigenous formations of Krutobalkivska suite. The main ore body is sampled from the surface in bulldozer trenches (available for observation, need clearing) and in many intersections of different level bore holes.

Fig. 6. Gold-bearing iron quartzite (Surozke deposit)

The deposit is 0.7km by 2.5km, coordinated to contact of metabasite rocks of Olzhynska suite with metaterrigenous formations of Krutobalkivska suite. Moreover, the deposit is characterized by localization of intersection node of three complex structured and variously oriented fractures: sublateral – Skifsky, North-West – Stepovy, and North-East – Sichny, which conditions the manifestation of the Ravine in modern relief. The ore bodies are immediately spacially connected with iron quartzite seams that are intensely limonitized to "iron hats". Magnetite quartzites contain iron minerals in the form of magnetite, tiger's eye can be found in this area(fine-fibrous pseudomorphosis of quartz in a mixture with goethite on asbestos-like ribecyte).

By ore composition, the deposits belong to gold-sulphide-quartz type. Free gold occurs in undulosed quartz on the contact with sulphides (50-80%), gold content (5-15%) is found in crystaljams with sulphides (pyrite, pyrrhotite, chalcopyrite) and magnetite. The rest (10-30%) is located in low-sulphide quartz, in fissures and mineral interstices. The gold is of high rate (926-933). Gold content in ores is between 3-5 g/t and in separate samples reaches 8-15 g/t.

Object under observation 4. Outcrop of Shevchenkivskyi plagiogranites along the Berda riv-

er. Osypenkivskyi plagiogranite massif. The route lies along the right and left banks of water stor-age basins, starting from no-name ravine, and stretching for 1.75km.

Osypenkivsky plagiogranitoid massif is located in the North part of Sorokinsky structure (see Fig. 3), intruding its South-West edges forming along them a continuous line of outcrops of crystalline base from the upper Kruta river to the far South of Sadova area of Sorokinska structure, stretching for about 8-9km. The width differs from 0.5 to 4km. The massif consists of plagiogranitoides of tonalite-plagiogranite formation. It also contains a wide range of ores presented mainly by abyssal and hypabyssal plagiogranitodes: hornblende diorite, quartz diorite; biotite, hornblende-biotite tonalites and plagiogranites, hornblende tonalites.

In tonalite outcrops along the Berda river, elements of texture irregularity are practically everywhere (freckles, stripes) conditioned by alternation of areas with different granularity.

Contacts of plagiogranitoides with country rock are well-marked with frequent overlapping, un-even outlines of contact interface. Thus, in outcrops of the left edge of the water storage basin of the Berda river, there are observed contacts of middle-coarse-grain massive tonalites and weakly gneiss-like tonalites with fine-grain thin-striped metabasalts. The area of contact changes is up to 7m thick and is presented by complete biotitization of metabasalts that are injected with a large number of quartz (quartz-pyrite) veins in the contact area.

Object under observation 5. Outcrop of rare-metal pegmatites (deposit of rare-metal pegmatites of Balka Kruta). Along the route, in separate small ledge rocks, are found outcrops of Shevchenkivsky granites, metabasites of Sorokynsky complex, schists and gneisses of Krutobalkivska suite. Among them, there are observed quartz-albite pegmatites of Balka Kruta deposit (Isakov, 2007; Gurskij, Esipchuk, Kalinin, Kulish, Nechaev, Tretyakov&Shumlyanskyi, 2005.) (Fig. 7).

Fig. 7. Ledge rock of rare-metal pegmatite of Balka Kruta deposit.

Pegmatites of rare-metal deposit of Balka Kruta occur in a small massif of basites of Sorokynsky complex and its junction zone with the biotite schist rock mass. In the deposit, there is a developed system of North-West and sub-lateral fractures, which makes the geological structure of the deposit more complex.

The establishing of pegmatites is connected with magmatic activisation and establishing of massifs of Saltychansky granites. As a result of massif formation, at the finishing stage, there were abruptions of solution-melt, and a system of fissures in granites and schist rock mass and metaultrabasites was formed. Pegmatite bodies are falling and tabular (sometimes mushroom-like) with length-thickness ration of 6:1 and more. Verticalwise, pegmatites make up a stratified "pie", within which about a dozen of pegmatite bodies are located.

General direction of vein dip is South-East 140^{o}withangles of 5-25^o. Some massive veins dip is directed Eastward under 20-35^o angles.

Pegmatites make up: a quartz core (*block quartz zone*); *block microcline* zone (mainly pale-pink and grey microcline). There are also a patch of crystals of pale-green spodumene up to 0.8m in dimension; *quartz - muscovite zone*, consisting of large packets of muscovite crystals of diamond shape; *albite zone* composed of sugary grained albite containing quartz, muscovite and very rarely – apatite with black tourmaline (schorl) (Fig. 8); *quartz-albite-spodumene zone* characterized by mainly consistent composition with quartz, albite and spodumene prevailing, with rarely occurring areas of quartz-spodumene composition; *quartz-albite zone* making up marginal parts of the majority of veins.Pegmatite of Kruta Balka are a small deposit of lithium and tantalum.

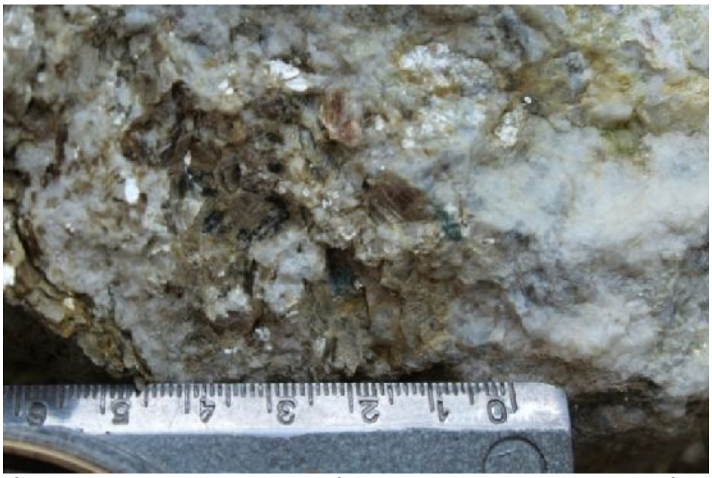

Fig. 8. Pegmatite (albitezone) ofBalkaKrutadeposit. Pegmatites of Kruta Balka are a small deposit of lithium and tantalum.

Object under observation 6. Quartz metasomatites (barren quartzites) across Saltychansky granites in outcrops on the right bank of the Berda river. Quartzite metasomatites form bodies with thickness up to 100m and length of up to 1.5km, usually associated with contacts of Saltychansky granites massifs. The most characteristic are “Donkey’s ears” rocks (Fig. 9) that make up a geomorphological and geological geosites. In their vicinity, these rocks partially crop out in a small abandoned quarry, where a zone of fracture can be observed with intensive manifestation of linear weathered layer. Quartzite rocks are composed of ledge rocks along the right bank of the river stretching for 170-200m. Quartzites making up narrow elevated crests are of light-grey to white colour, crevassed, plastic, with fine-scale mica. Quartzite bodies occur among pink and pink-grey biotite and biotite-amphibole middle- and coarse-grain granites of Saltychansky complex.

Fig. 9. Quartziterocks (“Donkey’sears”). Right bank of the Berda river.

Along with the offered geological tours along the Berda river and its tributary Berestova river, there can be observed practically uninterrupted ledge rocks of Pre-Cambrian formations encompassing rock formations of Western Pryazovian and Central Pryazivian series of Archean, as well as Shevchenkivsky Archean and Saltychanskyi Proterozoic complexes. Placed here geological monuments of nature can be a wonderful extension of the route or be subject to a separate independent route.

1. Rock chain along the left shore of the Berestova river. The rocky outcrop of Precambrian crystalline rocks on the left shore of the Berestova river in Karl Marx village are represented by relatively small ledges and separate blocks and boulders formed as a result of ruination of the rocky outcrop by the pro-cesses acting on the slope and weathering. They all belong to the Berestova tectonic zone and are composed of pink-grey biotite and amphibole-biotite average-grained granites and migmatites with xeno-lites of amphibolites. The rocks are characterized by heightened content of sillimanite, graphite found in the biotite gneiss, veins of quartz and quartzites, and veins of aplite-pegmatoid granites, which often occur there (Fig. 10).

Fig.10. The ridge of the rocks along the left bank of the Berestova River

2. Migmatite rocks in Troitske (Karl Marx) village. In the northern part of Karl Marx village, along the right shore of the Berestova river, near the place where a large tributary and a stream fall into the river, and 100 m away from the dam across the Berestova, there is a small group of rock outcrops slightly above the surrounding relief. They descend stepwise to the stream bed of the Berestova and down, along the current. The rocks consist of rocks of the Anadolsky Lower Archean complex which was first distinguished by N. I. Bezborodko in 1935. Macroscopically, these granites and migmatites are pink and grey-pink, leucocratic, biotite and amphibole-biotite, mixed-grained (average- and large grained) massive and unclearly striped, injectional-striped and spotted, at some places enriched with monazite, sillimanite, apatite and garnet, and contain xenolites of gneiss and amphibolites (Fig. 11).

Fig.11. Migmatite rocks in the village Troitske

3. Proterozoicnon-orequartzites. On the right from the road which lies along the water divide on the right slope of the valley of the Berestova river to Karl Marx village, there is an abandoned quarry, where non-ore quartzites were extracted. Quartzites are deposited as rather thick vein-like bodies (in this case, the observed thickness of the body, exposed from the surface by the quarry, is around 200 m) of non-ore quartzites among the granitoids of the Anadolsky complex. In the quarry on the Berestova river, quartzites are mined for road building. They are a fragment of surveyed Troitske deposit, the reserves of which equal 100 thousand tonsand are available for use in the glass industry and making acidic refractories. The quartzite are light grey to white, yellow-greyish, half-transparent, slightly cellular due to leaching, and lie among granitoids of the Anadolsky complex. Thickness of separate quartzitic veins reaches 21 m.

4. High rock above the Berestova. On the right shore of the Berestova river in the central part of Troitske village, on the river bend, a vertical wall of Upper Archean granitoids of the Shevchenkivsky complex closely approaches the river. The rocks are elevated up to 10-20 m and are observed as a narrow chain up the slope of the valley with distinctive ver-tical faults which divide them into separate narrow blocks and column-like formations. According to the composition, they are mostly pink and pink-grey biotite and amphibole-biotite plagiogranites and migmatites with veins of grey-light-pink aplite-pegma-toid granites with xenolites of amphibolites, with veins of yellowish-grey quartz. Rock outcrops in the area of Troitske village belong to the Berestovska tectonic zone with manifestations of cordierite-sillimanite mineralization, intense silification of the rocks, cataclasis zones (Fig. 12).

Fig. 12. High rock above the Berestova river.

5. NovosoldatskirocksontheBerda. The Novosoldatski rocks are a stripe of separated high rocky outcrops (up to 10 m) on the right shore of the Berda, below the place where it flows into the Berestova. The rocks are erosional buttes of a Precambrian basement, which has an elevated is location, exposed by the river erosion and changes caused by weathering. The rocks are composed of biotite greyish-pink and pink massifs, average-large grained granites, pink aplite and pegmatoid granites and migmatites, often with smoky quartz, with quartzitic veins. Granites belong to the Anadolsky complex (so-called Anatoliiski granites according to M. I. Bezborodko, 1935) of the Lower Proterozoic eon. The formation of this complex is considered to belong to orogenic stage of development of the Pryazovia region. The granites contain xenolites of gneiss and main crystalline schists (Fig. 13).

Fig. 13. Novosoldatski rocks on the Berda River

6. Mykolaivski granite rocks. On the left shore of the Berda, opposite Mykolaivka village, there is a continuous chain of a picturesque group of rocks. The rocks rise above the level of the valley up to 20-25 m, cut by small gullies on the sides with formations of small rapids, with large diversity of forms of weathering and erosional activity of streams. The rocks are composed by different ultrametamorphic, intrusive and metasomatic rocks of Archean and Proterozoic epochs. They include quite common graphite gneiss, overlapped by amphibolites, garnet, sillimate and amphibolite gneiss of the West Pryazovia seria. Also common are granites and migmatites of pink-grey and pink uniformly-grained type, veins of pink aplite-pegmatoid granites, dikes of serpentinous ultrabasic rocks and diabases.

In a more distant route, the following various geological objects can be offered for observation:

1. *Great Stone Rock, Gusarka vil.* (Bobrov, Sivoronov, Malyuk, Lisenko, 2002), located in the upper Sukha Konka river, between villages Gusarka and Konski Rozdory. Here, mainly on the left slope of the valley, a group of picturesque rocks crop out. Some of them are elevated above the river level (near the mouth of the Chabanka river) up to 25-30m. The rocks are composed by biotite and amphibole-biotite gneiss of the Western Pryazovia series with alternations of amphibolites, mainly intensively migmatized and interrupted by various granites and numerous veins of aplite-pegmatiod and pink porphyroblastic granites, with diabase dykes.

In the vicinity, next to Zrazkove vil., in a small quarry, there are outcrops of Pre-Cambrian monzonite intruding corund-silimanite-dichroite gneisses.

2. *Kamiani Mohyly (Stone Graves) Granite Massif.*The first reports about the geological structure of the region of location of the granite massif are traditionally attributed to Johann Anton Güldenstädt, who in August-September of 1774 traveled through Sloboda and left a detailed description of his surveys and observations. The nearest settlements he reached were Sloviansk and Bahmut, therefore it is no wonder that he failed to mention not only "Kamyana Mohyla" but any outcrops of crystalline rocks (Journey of Academician Gildenstedt in the Slobodsk-Ukrainian province, 1892). In 1787 with a geographical excursion organized by the Russian Academy of Sciences for studying the borderlands of Russia, Pryazovia was visited by Peter Simon Pallas, one of the most famous encyclopaedist scientists. He found outcrops of grey and red granites and gneiss covered by alluvium. It is unclear which outcrops he described, but the Besh-Tash rock massif, as Kamyana Mohyla was known at the time, was not mentioned by Pallas (Manyuk, Vol., Manyuk, Vad.V., 2017).

A bit later, in 1837, A. N. Demidov, a famous Ural oligarch sent a French engineer Frédéric Le Playto the Donbas. On the basis of his investigations, he developed geological maps of 1:265 000 and 1:420 000 scale of the territory, in the north-western part of which, the Kamyana Mohyla reserve is located. Besides, as A.B. Ivanitsky had done earlier, he described the rocks which would later be called mariupolites.

In 1880, O. V. Gurov for the first time conducted a stratigraphic division of the Priazovia crystalline complex. He classified the rocks which compose the red granite structures (intrusive rocks of "Kamiani Mohyla,, Katerynski granites) as rocks formed after the granite-gneiss rocks which contain them. V. O. Domger, a famous researcher of the southern Ukraine, discoverer of the Nikopol manganese ore deposit, in 1881 published a work devoted to crystalline rocks of south-west Russia.

In 1940, a geological survey on 1:50 000 scale was conducted, guided by experienced geologists N. T. Vadimova and V. N. Gladky, as a result of which, the "Kamyana mohyla" granite massif was for the first time studied in detail and its relatively young age was determined. Due to absence of radiometric dating, the age was determined as Paleosoic-Mesosoic, i.e. significantly younger than the actual age(Manyuk, Vol.V., Manyuk, Vad.V., 2017).

Among the studies conducted in the area later and which involved the massif, we should mention the Mariupol map sheet of 1:200 0000 scale, which was conducted by the geological party of the Priazovia expedition led by G. D. Kravchenko during the geological survey in 1957–1960. The study significantly elaborated the petrologic and mineralogical composition of the rocks of the intrusive massif, for the first time determined the presence of quartz-fluorite veins and veinlets, found such minerals as baryte, cassiterite, zinnwaldite and topaz determined the tectonic relationship between the intrusive rocks and the zone of the Rozivsky fault. The rocks of the Kamyana Mohyla area were determined to have an excessive content of rare soils, tantalum, niobium, molybdenum and tin. The absolute age was for the first time determined using radiometric dating, but due to disadvantages of the argon dating method provided a large range - 700 to 1600 M years. According to modern stratigraphic scale, this corresponds to the Middle and Late Proterozoic eon, but the authors consider the age of the pink granites as Paleozoic-Mesozoic, though this time interval is 542 – 251 M years (Fig.14).

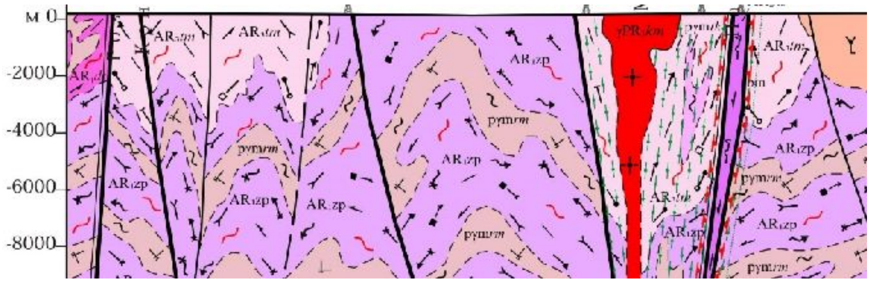

Fig.14. Kamenomogilskyi intrusive stock on the geological section

The first mention of peculiar granites of the Kamyana Mohyla and Katerynivks in Pryazovia in literature was made in the publications of I. G. Sagaidak (1937). As an integrated granite complex Kamyana Mohyla was determined by M. N. Ivantishny in 1960 and the name has remained in use after its initial appearance in the first variant of the unified stratigraphic schemes of the Precambrian Shield of Ukraine . Later, the peculiarities of the geological structure, mineralogy and petrography of the rocks of the complex were studied V. I. Kuzmenko (1946), V. N. Gladky (1958), U. U. Urk (1956, 1964), G. G. Konkov and R. M. Polunovsky (1964), L. F. Lavrynenko (1968), V. F. Razdorozhny (1985, 2004), V. V. Vasilchenko and others.

The granitoids of the complex were described in different levels of detail in a number of monographic publications, particularly "Metasomotites of the Eastern Pryazovia" (Liashkevych Z. M., 1971), "Mineralogy of Pryazovia" (Lazarenko E. K. et al., 1981), "Petrology, geochemistry and ore reserves of the intrusive granitoids of the Ukrainian shield" (Yesypchuk K. E. et al., 1990), "Petrology of the Ukrainian shield" (Scsherbakov I. B., 2005) and others (Esipchuk, Sheremet & Zinchenko, 1990).

Granite rocks of the *Kamiani Mohyly* form two lines with strike azimuth of 310° on the right slope of the Karatysh river. Separate hills are of significant dimensions and tower over the Karatysh river for 100-110m. Kamianomohylsky massif is composed of pink middle- and coarse-grain disseminated biotite granites of Kamianohomylsky complex dating back to Paleo-Proterosoic era (Fig.15). Mineral composition of the granites is: microcline, plagioclase, quartz, biotite, muscovite, fluorite and auxiliary minerals – topaz, xenotime, cassiterite, zircon, sphene, apatite, and often zinwaldite. Among subporphyritic granites, there are a significant number of veins and lenses of pegmatite up to 0.5m thick with cavities occasionally containing automorphic crystals of smoky and milky-white quartz, rock crystal and morion. The majority of granite outcrops, elements of the relief and natural landmark have their own names – Gostra (*Sharp*), Vitiaz (*Knight*), *Beshtash*, Liagushka *(Frog)*, Dolyna Masok (*Masks Valley).*

Fig. 15. Granite massif of Stone Graves

The rock formation Kamyana Mohyla belongs to one of the 25 promising objects of geological heritage of Ukraine, suggested for the European list. It is characterized by high level of geodiversity and, according to the criterion, meets most requirements for the contenders for the European network of geoparks.(GeologicalLandmarks (geosites) ofUkraine, 2011; Manyuk, 2005, 2006, 2007).The massif makes the basis for *Kamianomo-*

hylskyi steppe natural reserve (Bobrov, Sivoronov, Malyuk, Lisenko, 2002).

Here, next to Rozivka urban type settlement, in the Northern part of the "Kamiany Mohyly" natural reserve, one can observe a geological significant sight "*Contact of Kamiany Mohyly granite massif with gneiss-migmatite complex rocks"* represented by the contact of pink porphyroblastic granites of Kamianomohylsky complex with the rocks of Western Pryazovia seris of Paleo-Archean era.

3. *Outcrop of ceramic pegmatites of Zelena Mohyla (Green Grave) deposit in an abandoned quarry on the right bank of the Malyi Chokrak river in the vicinity of Yeliseevka vil.*The abandoned quarry is the most picturesque part of the relief and looks nothing like any other areas not only in Priazovia, but in Ukraine as a whole, and is conditioned by peculiarities of the worked out pegmatite veins. The ceramic pegmatite deposit was developed to extract ceramic raw materials in the 50-60s of the 20^{th} c., the majority of the veins are worked out. The remaining pegmatites are well cropped out in three quarries (Fig. 16). It is located within the Obytochnenska syncline in the basin of the Chokrak river and is composed of the Zelena Mohyla, Belyky Tabir Ravine and other deposits. Their location is related to the ancient Chokrak fault orientated towards the north-west. The deposit consists of four large pegmatite veins with apophyses and a range of smaller ones.

Enclosing rocks are mainly migmatites of diorite composition, and in a smaller extent migmatites of granite composition. Migmatites stretch in the North-West direction with the azimuth of 345–360°. The dip is steep 78–86° directed westward, and in the western part of the deposit it is directed eastward. Migmatites are contorted into fine isosynclinal wrinkles that complicate a thick anticline fold. The largest pegmatite bodies are associated with the central part of the anticline. The pegmatites of the deposit stretch from North to South for 0.8-1.0km. They have both matched and transverse contacts, as well as a range of apophyses separating from the main veins in different directions. A small number of lesser veins have sub-lateral strike and gentle northward dip (15–20°). The length of the largest vein ranges between 60-190m being from 5-10m to 80-96m wide. The majority of veins are practically not zonary, the change of one structural feature by another is fixed as frequently irregular by dip and thickness.

Fig. 16. Yelyseyevskyi quarry for extracting pegmatite deposits of Zelena Mohyla (Green Tomb)

At some places there is accessory rare-soil-rare metal mineralization represented by columbite, tantalite, zircon, beryl, monazite and wolframite. The rock structure is mainly pegmatiod and granite, the texture is lens-shaped and striped. By mineral composition, pegmatites are microline-oligoclase, and much rarer – oligoclase-microcline, some bodies are albite-oligoclase-microcline. Mica is presented by biotite and muscovite.

4. *Ceramic pegmatites of the jointing of Balka Velykogo Taboru deposit (of the same-name quarry).* The deposit is located 2.5km to the West of Yeliseivka vil. in the interstream area between this ravine and the Chokrak river. It contains up to 80% of the proven resources of pegmatites in Ukraine. Within this jointing, three veins - #1, 11 and 12 – were explored in the same-name deposit between 1956 and 1958.

By mineral composition, pegmatites of the jointing are presented by plagioclase and plagioclase-microcline types. Among mafic minerals are biotite, muscovite, garnet, occasionally magnetite. Mass content of K_2O in the rock ranges within 1.53–3.74 % (average – 2.08 %), Na_2O – 5.20–7.45 % (average – 6.05 %).K_2O/Na_2O ratio is from 0.01:1 to 2:1. Feldspar along with quartz makes up up to 90% of the rock.

Pegmatite veins of “Balka Velykogo Taboru” deposit are mainly composed of pegmatites of indistinctly graphic (51.1%) and graphic (33%) structure. Pegmatites of pegmatiod, grain and block structure (1.1%) are less significant. Pegmatites of graphic structure, are usually pind and bright-pink rock mainly composed of microcline, and regularly grows in long quartz crystals (“ichthyoglypts”). Plagioclase is less frequent. The most typical composition of graphic pegmatite is: microcline – 50-75%;biotite+muscovite – from 0 to 3%; plagioclase – 3-15%; ore – up to 1%; quartz – 20-35%; minerals – up to 1%. Averagecompositionofpegmatiteofindistinctlygraphicstructureis: microcline - 20-50%; plagioclase - 10-40%; quartz - 20-40%; biotite+muscovite — 3%. Pegmatite of indistinctly graphic structure is mainly the product of recrystallization and albitization of graphic pegmatites.

5. *Outcrops of Obitochnenskyi diorites in an abandoned quarry on the right bank of the Obitochna river.* In ledge rocks on the pit walls, diorites of Obitochnenskyi complex crop out. Diorites are dark-green to dark-grey colour, middle- to coarse-grain, mainly massive. Mineral composition of diorites is: plagioclase - 40-60 %, hornblende-30-50 %, biotite - 1-7 %, quartzup to 3-5 %, clinopyroxene up to 5 %. Hornblende in the diorites has bluish-green colour. In the outcrops along the Obitochna river, the same diorites crop out, further along the route down the river, the diorites are changed by migmatites of Remivsky complex. Among the diorites, occasionally veins of pegmatites and aplites can be observed.

6. *Saltychanski granites on Kamiana Mohyla mount.* The outcrop is located at the extreme point of the mountain in a small quarry of oval shape about 100m in the length and width (Fig. 17). The height of the edge is up to 60m. On the microscopic scale they are light-grey, fine- and medium-grain granites. Mineral composition is the following: the main body is plagioclase (70-80%), quartz (10%), biotite (8%) and orthite (2%). The granites of the quarry are characterized by homogeneity and consistency of the texture and mineral composition. Sometimes, there occur xenolithes of basic rocks, occasionally adding the rock migmatite appearance. There occur thin aplite veins. The minerals surrounding orthite grain have apparently changed colouring because of orthite influence.

Fig. 17. Abandoned quarry on Mount Tomb Korsak.

Fig. 18 Korsak Mohyla geological monument (geosite)

7. *Ferruginous quartzite of Korsak-Mohyla (GeologicalLandmarks (geosites) ofUkraine, 2011; Manyuk, 2005, 2006, 2007).* The relief of Korsak-Mohyla is presented by two parallel belts of island-

mountains stretching in North-West direction and separated by a ravine. The western belt consists of 5 hills, the highest being 138.4m, while the eastern one has one hill 124.3m high, the surface around the hills is elevated at 90.0m. An abandoned quarry is located on top of the hill (Fig. 18), where rich iron ores were extracted at the beginning of the last century.

The belts are composed by rocks of Demianivska suite of Central Pryazovian series. The lower part of the suite is composed by barren indistinctly laminated quartzites with the thickness up to 40m with assises of biotite-pyroxene schists. The middle part is composed of the interchanging pyroxene-magnetite and magnetite quartz with fine-grain quartzites and characteristic bands of biotite-plagioclase and graphit-garnet-biotite-microcline gneisses. The upper part of the suite is composed of light-grey and greenish-grey, scaly, gneisses of different composition. For the whole section, multiple veins of microcline and plagioclase granites as well as general mineralization are characteristic.

8. *Nyziansky and tokmatski granites of Tokmak-Mohyla* in the vicinity of Novopoltavks vil. Tokmak-Mohyla or Synia Gora (*Blue Mount*) (Fig. 19, 20) is an island-mountain composed of granites of Nyzianska association of Late Archean with the ground level of 307.0m. The country rocks are gneisses and migmatites of Western Pryazovia series, charnokites and enderbites of Tokmatski complex. Nyzianski granites are leucocratic microcline granites. They are pink, leucocratic, inequigranular massif or slightly banded rock. Nyzianski granites together with Tokmakski enderbites at the foot of the hill are stripped in the Novopoltavski quarry located nearby.

Fig.19. Tokmak-Tomb or Synia Gora (Blue Mountain)

Fig. 20. Novopoltavsky quarry on the Blue Mountain

Conclusion. Western Pryazovia belongs to one of the most attractive regions for development of geotourism with high concentration of unique objects of geological heritage. it was determined that the most promising place for developing tourist routes is the outcrop of crystalline Precambrian rocks along the Berda river and in the surrounding territories. The outcrops represent a practically full section of rock associations of the Osypenivska Archean seria, which form Olhinska metabasite and steep-bank metasedimental suites; intrusive and ultrametamorphic formations which compose the Osypenivsky gabbro-diorite, the Shevchenkivsky plagiogranite-tonalite and the Saltychansky granite complexes. This small area includes places exposed to direct observation - deposits of gold (Surozke), rare metals (Kruta Balka), ceramic pegmatites (Mohyla Zelena and Velyky Tabir Ravine), iron (Korsak-Mohyla). These objects provide a full image of the structure of the crystalline structure of the West Pryazovia megastructure of the Ukrainian shield. The outcrops of the crystalline Precambrian rocks in Western Pryazovia, suggested as geotouristic objects have been identified and described. A small proportion of these objects are geological relics which have an official protection status and are included in the List of the Nature-Reserve Fund of Ukraine, other are promising geosites, whose inclusion in the list is an important task in the development of this fund and for the preservation of unique geological heritage for the future generations. We have formulated the main recommendations for preparation and activation of geotouristic routes in Ukraine. We have suggested and described the objects of geotourism in Western Pryazovia which can certainly be developed and activated in the near future.

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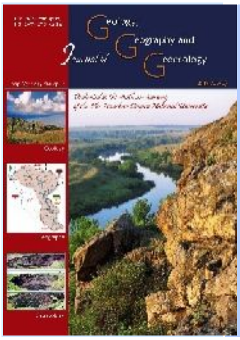

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Media tourism in the Chernobyl Exclusion Zone as a new tourist phenomenon

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Abstract. Every year, the number of tourists in the Chernobyl Exclusion Zone is increasing. The most numerous visitors are journalists who come to perform their official duties. At the same time, researchers have not yet shown interest in such an interesting and important tourist phenomenon. The purpose of this article is to describe a new phenomenon of media tourism in the Chernobyl Exclusion Zone and its features. The study was conducted with a help of a qualitative case study analysis method. The websites of the state and private enterprises and mass media publications based on the results of trips to the territory for 2013-2017 were analyzed. As a result, the specific features of journalists who visit the Chernobyl Exclusion Zone were identified. Such journalists mainly have confidence in the absence of a threat to health (55%), developed empathy (45%) and imagination of thinking (45%). Consequently, the tragedy of history and the gloomy appearance of the territory, the suffering of local residents make it attractive to journalists. In addition, due to personal interest, the voluntary travel motive (61,5%) prevails over conditional forced travel (38,5%). At the same time, the attention of journalists to the territory is attracted due to the activities of tourists. The authors describe the so-called «compensation effect», when the reduction of tourists' attention to the territory is balanced by an increase in the attention of the mass media. The presence of risk explains the predominance of men among journalists in the Chernobyl Exclusion Zone (54%). For example, women can better assess the risk due to greater vulnerability. The peculiarity of journalists' work in the Chernobyl Exclusion Zone is the risk of radiation exposure and ethical controversy. The study shows that journalists' inherent positive world perception and profound sense of professional duty can successfully overcome these obstacles. The results of the study can be used by the following researchers to identify ways and strategies for promoting media tourism in the Chernobyl Exclusion Zone. The benefit of this study is to draw attention to a new unexplored tourist phenomenon. Mass media have a great influence on the formation of a positive attitude towards the territory and attracting the attention of tourists. Taking into account the specific features of media tourism will help to attract more tourists and improve the quality of rendering service to journalists.

Keywords: journalists, mass-media, tourism, Chernobyl exclusion zone.

Медійний туризм у Чорнобильській зоні відчуження як новий туристичний феномен

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Анотація. Щорічне збільшення туристичної активності у Чорнобильській зоні відчуження привертає увагу журналістів до цієї території. При цьому дослідники досі не виявили інтересу до цього феномену. Мета статті – описати новий феномен медійного туризму у Чорнобильській зоні відчуження та його особливості. Невивченість цього явища змусила звернутися до якісного експлоративного методу, який дозволяє описати новий феномен та надати матеріал для настуних досліджень. У статті описано діяльність державного та приватного підприємств з надання організаційно-інформаційних послуг журналістам. З'ясовано особистісні якості журналістів, які змушують їх здійснювати таку поїздку. Наприклад, переконаність у відсутності загрози для здоров'я (55%), здатність співпереживати (45%) та образність мислення (45%) привертають увагу журналістів до цієї території. Більше того, особиста зацікавленість пояснює переважання добровільного мотиву поїздки (61,5%) над умовно вимушеним командируванням (38,5%). Встановлено, що серед журналістів у ЧЗВ переважають чоловіки (54%) через їхню меншу здатність до оцінки ризику. З'ясовано особливості роботи журналістів у Чорнобильській зоні відчуження, які відрізняють її від роботи на інших територіях. Охарактеризовано закономірності зв'язку кількості публікацій мас-медіа з описом туристичного досвіду та кількості туристів. Авторами описано так званий «ефект компенсації», коли зменшення уваги туристів до території компенсується збільшенням уваги мас-медіа.

Ключові слова: журналісти, мас-медіа, туризм, Чорнобильська зона відчуження.

Introduction. The Chernobyl accident has caused the phenomenon of Chornobyl's journalism to come to life. The first visitors to Chernobyl after the explosion were precisely the journalists who performed the professional responsibility for documenting the scale and consequences of the accident (Kuzmych-Pohodenko, 2015).

By its number, representatives of the Ukrainian and foreign mass media are the second group of visitors after foreign scientists conducting research in the Chernobyl Exclusion Zone (CEZ) together with Ukrainian counterparts (Golovata, 2010).

Dark tourism, which includes tourism in the CEZ, is today a promising area. The term was first used by researchers J. Lennon and M. Foley to mark the tourist interest in places of recent deaths, catastrophes and crimes (Foley, Lennon, 1996). The CEZ is one of the most famous destinations of this type (Yankovska, Hannam, 2014). The fact that the authoritative economic edition Forbes recognized the Chernobyl Nuclear Power Plant (ChNPP) as one of the most exotic places for tourism in the world also contributes to the popularity of the territory among tourists (Forbes, 2009).

It should be noted that there is no unanimity among the researchers regarding the classification of journalists' travel in the CEZ as tourists. Some researchers suggest classifying Chernobyl journalism as business tourism and emphasize the professional preconditions for such visits (Pestushko, Chubuk, 2010; Derkach, 2014). In this article we will follow this very approach, because often the purpose of journalists' travel to the CEZ is to cover the tourist attractions of the infected area and its state within the limits of their professional activity. At the same time, mass media follow certain tourist routes, developed according to their professional interests. It is clear that journalists can come to excursions to the CEZ as ordinary tourists. That is, such a trip will be carried out for recreational and cognitive purposes, and not within the framework of professional activity. Such visits can not be considered as media tourism and are not regarded in our article.

The scientific literature on the topic emphasizes the decisive role of the media in promoting dark tourism, in particular in the CEZ (Butler, 1990; Kim, Richardson, 2003; Iwashita, 2006; Young; Young; 2008; Yankovska, Hannam, 2014). Other authors emphasize that the study of the phenomenon of Chernobyl's journalism, despite the significance of such activity, has not yet become relevant in scientific circles (Kuzmych-Pohodenko, 2015).

The urgency of the study is conditioned by the lack of research on media tourism in the CEZ, as well as the growing popularity of tourism in the CEZ.

The purpose of the study is to describe a new phenomenon of media tourism in the CEZ and its features.

Accordingly, the following tasks are set:

- to analyze the activities of tourist enterprises and state institutions for organizing travel of journalists to the CEZ;
- to analyze the materials of the media, prepared according to the results of visiting the CEZ;
- to analyze the legal acts regulating the legal aspects of the activity in the CEZ.

Methods and materials. This study was conducted with a help of a qualitative case study analysis method. R. Yin explains the usage of this method by the necessity to understand complex social phenomena and generalize them to make theoretical assumptions (Yin, 2009). Appeal to this method is justified by the insufficient attention of researchers to the phenomenon of media tourism in the CEZ. This situation has led to the necessity to describe it and to provide the next researchers with material for quantitative research and testing of hypotheses.

For analysis, sites of two companies - the State Agency of Ukraine on Exclusion Zone Management (SAUEZM) (Derzhavne agentstvo Ukrai'ny z upravlinnja zonoju vidchuzhennja, 2018) and Chernobyl-tour (Chernobyl-tur, 2018) were selected. This choice was dictated by their exclusive role in the organization of tourism activities in the CEZ. SAUEZM manages access to the CEZ, makes the issuance of permits for all official visits and approves their programs. The State Enterprise «Technical and Information Support Management Center of the exclusion zone» (TISMCEZ), which is in the field of SAUEZM management, regulates tourism activity in the CEZ. The function of the company is the organization of visits to CEZ for journalists of Ukrainian and foreign mass media and their information support.

The Kyiv Travel Agency «Chernobyl-tour» is a leading private travel agency that provides targeted organizational and information services to mass media representatives in the CEZ. The information agency of the company cooperates with leading world mass media such as The Times, Forbes, Associated Press, BBC, Discovery, Lonely Planet and many others.

The search on the site SAUEZM for the keywords «tourism», «journalists» provided only 23 publications for the period 2016-2017 years. On the site of the travel agency «Chernobyl-tour»we were interested in the tabs «Information agency» and «Media and Chernobyl-tour». The content of these materials is directly connected with cooperation with journalists and reflects their tourism activities in the CEZ. In particular, in the «Media and Chernobyl-tour» tab, there are 9 mass media publications following the 2010-2016 trips.

The research of mass media publications took place during the year, starting from July 2017. We made a request to the Google search engine for the keywords «Chernobyl», «journalists». So the search was limited by territorial and professional background. The criterion for selecting publications for research is their publication based on the results of the trip to the CEZ. Only 20% of the publications met this criterion, while others were ignored. All investigated materials were exceptionally based on information resources. These materials can be divided into three thematic groups: coverage of the newsbreak, research of the current state of the territory and a description of the tourist trip. In total, 1300 pages of text, 75 hours of video, 29 forums were analyzed. All videos were transcribed, comments on the forums were collected manually and recorded.

For information on the dynamics of the journalists' visit to the CEZ over the past 5-10 years, we have sent a formal request to the SAUEZM. The answer is that there is no separate record of journalists' visits, that is why the requested information can not be provided. The corresponding request was also sent to the office of the tourist agency «Chernobyl-tour», but no replies were received.

We sought to find out whether an increase in tourist flows provokes the interest of the media or the publication attracts tourists to the territory. Successively we restricted the chronological range of search from January 1 to December 31, 2013, 2014, 2015, 2016, 2017. The first 1,000 of the total volume of relevant results were investigated in each case. We guessed that only publications about tourist routes connected with tourist interest. Then we formed a theoretical sample of 10 materials in which the phenomenon studied is expressed in the purest and most transparent form (Eisenhardt, 1989). According to Eisenhardt, «the purpose of the theoretical sample is the selection of cases that can expand the emerging theory». This made it possible to verify that namely publications describing tourist experience are related with the dynamics of tourism flows. We have established a strong positive correlation between the number of visitors to the CEZ and the number of available materials about this territory (the correlation coefficient is 0.8021 at p <= (less or equal to 0.05). We cited quotes from these materials further for visibility of some of our conclusions.

We assumed that visiting the CEZ requires a journalist to have certain characterological features. Our task was to make a portrait of such a journalist. We also wondered if there was a connection between sex and interest in such visits. We encoded the following categories: (1) purpose - the reason for the trip; (2) motive - an impulse to travel (coercion or good will); (3) sexual affiliation (male, female); (4) character - the specific personality traits of journalists who visited the territory. The last category included those fragments of journalistic materials that clearly traced the manifestation of some aspect of the personality of the journalist. All encodings were manually processed in the Excel file. First, each of us analyzed the materials for these categories, after which we discussed the results and ideas that arose. Each of us got identical results, with the exception of the last category. We got both identical and different results.

At the second stage, we analyzed each publication by category (1) «positive world perception», (2) «confidence in the absence of a threat to health», (3) «profound sense of professional duty», (4) «curiosity», (5) «impressionability», (6), «inclination to sensationalism» (7), «developed empathy», (8) «household unpretentiousness», and (9) «imagination of thinking». Finally, we recorded the part of publications containing each of the categories. Our results were identical.

To verify the correctness of our study, we provided preliminary conclusions at each stage to experts in the field of economics and tourism management (Lincoln, Guba, 1985). The remarks made in each case were taken into account when necessary having gathered additional information on the topic (Alvesson, Kärreman, 2007). To confirm our assertions, we compared the obtained results with the typology developed by Myers-Briggs, which is used to determine the occupational inclination of individuals. Specific features of journalists in the CEZ correspond to their professional features. We also contacted the jobseekers websites Career Cast and Superjob, which empirically confirmed the inherent nature of the gender and personality traits of journalists in the CEZ.

Results. *Organizational aspect of media tourism in the CEZ. Organizational activity of state enterprises.* 2016 was declared a year in memory of the participants in the liquidation of the Chernobyl accident and the victims of the Chernobyl disaster, which dates back to the 30th anniversary of the tragedy. In connection with this, the SAUEZM together with the enterprises of the sphere of its management organized events for visitors. During these events, state institutions reported on the course of liquidation of the consequences of the accident, the work on reducing the radiation hazard, the results of the implementation of international projects, the current state of CEZ, etc. (Derzhavne agentstvo Ukraiʹny z zapravlinnja zonoju vidchuzhennja, 2016). The necessity to attract the attention of the world community to the problems of CEZ and liquidators has led to special measures for media workers. This led to a significant increase in journalists' tourism activity in the CEZ.

On April 22, 2016, the SAUEZM together with the TISMCEZ organized a press tour (an event for journalists - excursion) for the representatives of the Ukrainian and foreign mass media. The purpose of the tour was to familiarize journalists with the work of enterprises, the status of implementation of international projects and the prospect of reforming the CEZ. The journalists attended the briefing of the head of the agency, visited the observation deck of the Shelter Object to familiarize themselves with the progress of the construction of a new safe confinement, learned about the progress of work on the storage of spent nuclear fuel (ISF-2), talked with ChNPP chief engineer on its further functioning, and at the end of the tour, they visited Pripyat, where they could see how the city changed over 30 years after the resettlement of residents (Derzhavne agentstvo Ukrai'ny z upravlinnja zonoju vidchuzhennja, 2016).

The commemoration of the 30th anniversary of the Chernobyl accident has attracted the attention of not only Ukrainian but also world media. At the end of February 2016, the CEZ was visited by a crew of the BBC Scottish office for the filming of the special program «Europe» for this date. The journalists set out to show the consequences of the accident and the changes that occurred after it. Accompanied by the specialists of the TISMCEZ, they interviewed the liquidators of the accident, got acquainted with the work of the measuring center «EcoCenter», visited the observation deck of the Shelter Object, the city of Pripyat. As a result of the trip, a 30-minute film was prepared (Derzhavne agentstvo Ukrai'ny z upravlinnja zonoju vidchuzhennja, 2016).

Organizational activity of private enterprises. The task of the staff of the tourist agency «Chernobyl-tour» is to make the journalists' visit to the CEZ as comfortable and productive as possible. Their duties include organizing a working visit, conducting excursions for journalists, providing interviews, information on the Chernobyl accident and its consequences, the current state and prospects for the development of the CEZ, providing advice on correct and scientifically accurate coverage of this information in the media. They also search for speakers for interviews, organize meetings with eyewitnesses and liquidators of the accident, «self-settlers», specialists (CEZ staff and research institutes), develop individual programs for visiting the objects of the CEZ.

Employees of the company are experienced specialists in the Chernobyl accident, ecology, tourism, eyewitnesses and liquidators of the accident, who have accumulated a great deal of knowledge about the CEZ and related issues. They conduct lectures and trainings on radiation treatment, survival in the event of man-made disasters, organize aviation tours over the CEZ (Chernobyl'-tur, 2018). It precents grate interest to the jounalist community, as it is a potentially interesting to the mass media audience, an unusual and vivid news opportunity. They also provide accurate, up-to-date, literally interpreted information on the Chernobyl accident and other man-made disasters and their consequences through their own research unit, presenting it as interesting and accessible (Chernobyl-tur, 2018). It attracts to CEZ journalists who are trying to satisfy the interest of their audience to the actual and popular tourist destination.

The task of the Chernobyl-tour agency is also the organization of special events with the participation of mass media. So, on May 20, 2016, a field seminar "Representation of cultural, historical and natural values of the CEZ for Ukraine and the world: searching for effective paths and forms" was organized together with the SAUEZM. Journalists from leading tourist mass media were invited to participate as mediators in this process. The event was held in the form of a one-day visit to the CEZ on the basis of the standard program of «Chernobyl-tour». To participate in the seminar, each participant was required to pay a registration fee of 300 UAH. The program includes the gathering and departure from Kiev, the visit to the most famous locations of the CEZ (city of Pripyat, the former secret city of Chernobyl-2, the city of Chernobyl, with a visit to the exhibition exposition of the national culture of the Chernobyl Polissya, opened to the 30th anniversary of the accident, etc.), traditional feeding of the Chernobyl catfishes, lunch in the CEZ, professional discussion and coming back to Kiev (Chernobyl-tur, 2018).

«Chernobyl-tour» announces the purpose of its activities as the elimination of information «pollution» in a society that arose after the Chernobyl accident (Chernobyl-tur, 2018). The agency plays an extraordinary role in increasing mass media literacy, and, through the mass media, eliminating the world's ignorance of the disaster-related issues. The unique feature of «Chernobyl-tour» is that the provision of such comprehensive information requires extensive knowledge and experience from various fields, which puts it over the competition in the sphere of organizational and informational service of journalists in the CEZ.

The economic aspect of media tourism in the CEZ. Understanding and peculiarities of media tourism in the CEZ. The materials of the media and the official websites of SAUEZM and «Chernobyl-tour» use the terms «press tour», «excursion», «field seminar» to define journalists' visits to the CEZ.This, as well as the presence of tourist services for journalists and their integration into the generaltour-ist system of the CEZ, gives grounds for classifying it as a type of business tourism - media, that is, connected with the performance of official duties by mass media. At the same time, specific features of the territory determine a certain type of journalist's character. As can be seen from the Table, the voluntary motive of a journalist's visit prevails over forced ones. In addition, most voluntary visits are due to the desire to gain their own tourist experience. Journalists arriving at the CEZ have specific personality traits. For example, they have strong confidence in the absence of a threat to health (55%), developed empathy (45%) and imagination of thinking (45%). These results make it possible to understand how the professional peculiarities of journalists are related to the choice of the trip and the motivation for it.

Table. The personal and professional features of journalists in the CEZ

The motive of the visit	***The part of materials***	***The purpose of the visit***	***The part of materials***
Business trip from the editorial board	*38,5%*	*Coverageofthenewsbreak (fire, openingthehostel)*	*38,5%*
Self-initiated trip	*61,5%*	*Gaining own travel experience*	*38,5%*
		Independent search for information as for material (life of residents, restoration of flora and fauna)	*23%*

Continuation of the Table

Personality traits of journalists	***The part of materials***	***Journalists' quotation***
positive world perception	*27%*	*«We get on the bus and giggle nervously. Jokes about how nicely and radioactive we will glow after returning, are present». Kateryna Gorodnycha. Insider*
confidence in the ab-sence of a threat to health	*55%*	*«Concentration of radionuclides in the atmosphere is so small, that is can not be harmful to health». Ivan Vorobjov. TSN*
profound sense of professional duty	*18%*	*«I came here for two weeks, my colleagues and I are shooting a documentary about life in the exclusion zone. I was afraid to stay here at first. But now the fear has gone. I work all the time, I do not think much about comfort». British journalist Robert*
curiosity	*18%*	*«And in case of unforeseen situations, there are automated probes, which are controlled from the neighboring premises by workers. We ask for permission to test them, although we are not a success at once». Sergej Revera Segodnja*
impressionability	*36%*	*«The first half an hour of the trip through the Zone did not fit into my idea about it. Straight roads, neat houses, well-kept monuments. The stronger was the shock of visiting the kindergarten in the village of Kopachi. It was an instant transfer from our world - the world of those who say, regret, remember into the world of those for whom this tragedy is not something abstract, but part of life, a turning point». Kirill Voronkov. Odesskaja zhizn'*
inclination to sensatio-nalism	*27%*	*«In the pursuit of entertainment, some journalists like to show huge catfish living under the bridge, grown to such a size because of radiation. Catfish here, indeed, are large (but not huge), due to the fact that they are not caught, but only fed». "Kirill Voronkov. Odesskaja zhizn'*
developed empathy	*45%*	*«I would have become drunk myself here. I imagine, you are sitting in a radioactive forest, guarding radioactive waste for 10 000 UAH per month and you understand that in your village where there is no work, this is a very big money ...» Olena Golubjeva. 112.ua*
household unpreten-tiousness	*18%*	*«Very slow wi-fi there. My TV does not work. But I do not really need it. I came to shoot abandoned school. But in general, the comfort in the hotel is quite good: it is tidy». Tim Browning, London television operator*
imagination of thinking	*45%*	*«The zone is perceived as a territory on the border of two different societies, a mirror of history, where time has stopped». The author is not marked. Ukrai'ns'ki novyny*

The CEZ media tourism has the following features:

- deviation from the approved route is prohibited;
- the trip is carried out under the supervision of the escort;
- shouting of some objects of the visit is prohibited;
- pre-instructuons and following radiation safety rules are obligatory;
- a pre-authorized permission must be obtained;
- absence of medical contraindications.

In the written request for travel, in addition to personal and contact information, the term and purpose (video, photographing, preparation of report) of staying, the route of visit, the journalist must indicate the nature and extent of the information that he plans to receive; the people with whom he plans to meet. The request is sent by e-mail to the head of SAUEZM at least 10 working days prior to the visit. According to the results of the consideration of the application, permission or motivated refusal are given (Derzhavne agentstvo Ukrai'ny z upravlinnja zonoju vidchuzhennja, 2018).

Influence of general increase of tourist activity. Every year, tourist flows to the CEZ are increasing (Fig.1). At the same time, about 2/3 of tourists are foreigners. Only a year after the commemoration in 2016, the 30th anniversary of the tragedy, the number of tourists increased by 35% (by 12977 people). There is a high interest of the world community to the present state of the territory, but not technical innovations in the CEZ.In particular, tourists are interested in the changes that took place in the city of Pripyat in the 30 years after the largest man-made disaster in the world and the resettlement of residents (Derzhavne agentstvo Ukrai'ny z upravlinnja zonoju vidchuzhennja, 2016).

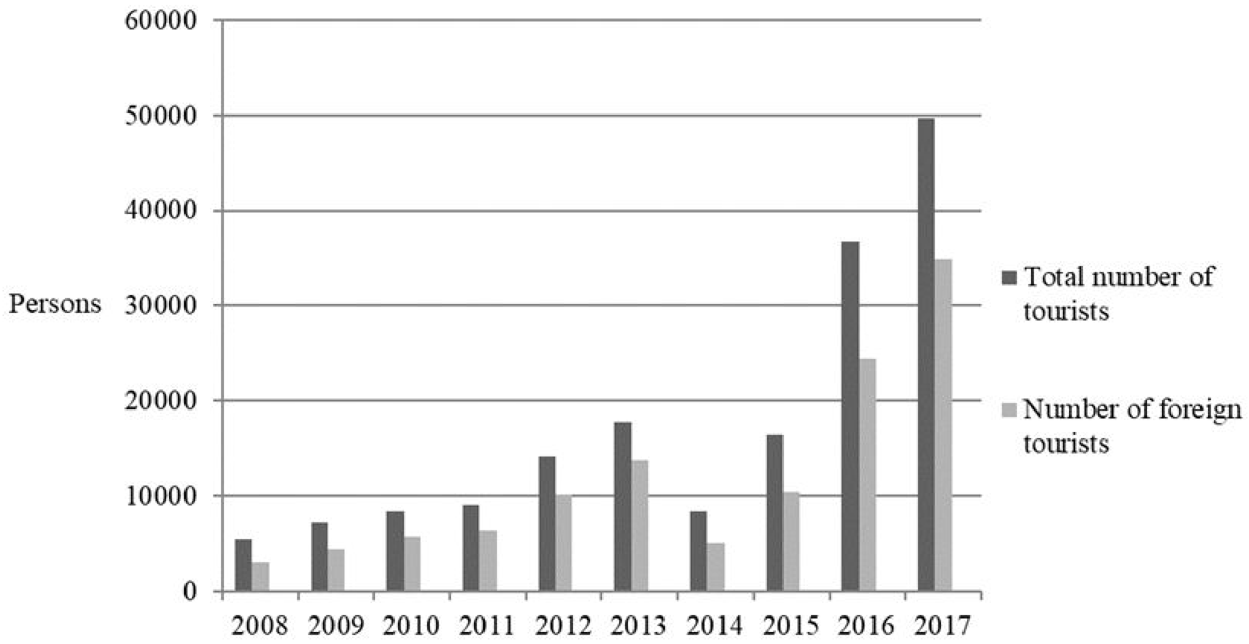

Fig. 1. Dynamics of tourists' visits in the Chernobyl exclusion zone in 2008-2017, persons (built according to the data of Derzhavne agentstvo Ukrai'ny z upravlinnja zonoju vidchuzhennja, 2017)

Companies that organize visits to the CEZ allow the citizens of Ukraine and other countries to receive information on the state of the territory and works on it, in particular, through mass media. Therefore, according to an increase of the total number of tourists, the number of journalists' visits to the CEZ increases.A particular increase in journalist activity in this territory is observed during the commemoration of the anniversary of the Chernobyl disaster.

Taking into account the growth of tourist demand, SAUEZM takes measures to form positive public opinion on the radioactive and ecological state of the territory, the work on the elimination of the consequences of the accident and the management of radioactive waste. To improve the quality of tourist service, a secure infrastructure is created, new routes are being developed. Tour operators are invited for a dialogue, competitive working conditions are promised (Derzhavne agentstvo Ukrai'ny z upravlinnja zonoju vidchuzhennja, 2016). Journalists are actively involved to form a positive image of the territory.

The journalists themselves in their materials note that their attention to the territory was attracted by a steady increase of tourist interest to it. Here are some examples of journalist materials.

«In recent years, Ukrainians have increasingly become involved in proposals for domestic tourism. In addition to the «classic» trips to Kiev, Lviv, Odessa and the Carpathians, there are also non-standard offers - a mixture of exotic and extreme tours to the Chernobyl exclusion zone. One-, two- and even three-day tours are offered. I chose for myself a study tour for one day» (Kyryll Voronkov, Odesskaja zhyzn', 2017).

«Every year the zone of exclusion around Chernobyl is becoming an increasingly popular tourist destination. Not only Ukrainians, but also foreigners go there. «Vesti» visited one of these trips and found out what things interested foreign guests in Chernobyl and what they were told by our guides. The most favorite points of the tour pro-

gram are animals, self-settlers and that disastrous reactor number four. The highlight of the trip is lunch in the canteen in Chernobyl» (Jaroslav Markyn, Vesty, 2017).

«The dummy dressed in protective clothing meets all legal stalkers at the checkpoint «Dityatki». According to the smiling guide, there is a caste of people who visit Chernobyl exactly in this guise, in order to play the role of characters from the famous computer game. This time, shortly before the 32nd anniversary of the catastrophe, the Dnipro journalists decided to check whether it is dangerous for tourists in the 30-kilometer zone, and how Chernobyl catches the souls of visitors» (Kateryna Gacenko, Ruslan Beljavskyj, Nashe mysto, 2018).

Thus, tourists attract journalists' attention to tourist routes in the CEZ and force them to describe their tourist experience, and not vice versa. As it may be seen from fig. 2, an increase in the number of tourists in the CEZ leads to a decrease in the number of mass media publications, and vice versa, which we called the «compensation effect». In periods when society is interested in the territory, there is no necessity to attract attention to it in mass media. Reducing the attention of tourists to the territory is compensated by the increased attention of the mass media. The exception is only 2016, when the commemoration of the 30th anniversary of the Chernobyl disaster caused a high interest among both tourists and journalists.

We see a strong positive correlation between the number of visitors to the CEZ and the total number of available materials about this territory. The correlation coefficient is 0.8021 at p <= (less or equal to) 0.05 (Fig. 2). The coefficient is calculated on the assumption that the number of articles for the reporting period can not be considered without previous publications. The previous articles form an information layer that stimulates interest to the territory and the demand of new journalistic materials. The decline in the number of visits in 2014-2015 is primarily due to a decrease in the level of socio-political stability in Ukraine and a military conflict in the territory of Eastern Ukraine. While the growth of tourist interest in 2015-2016 is associated with a decrease in society's fear of hostilities. This, in turn, attracts the attention of journalists to the territory.

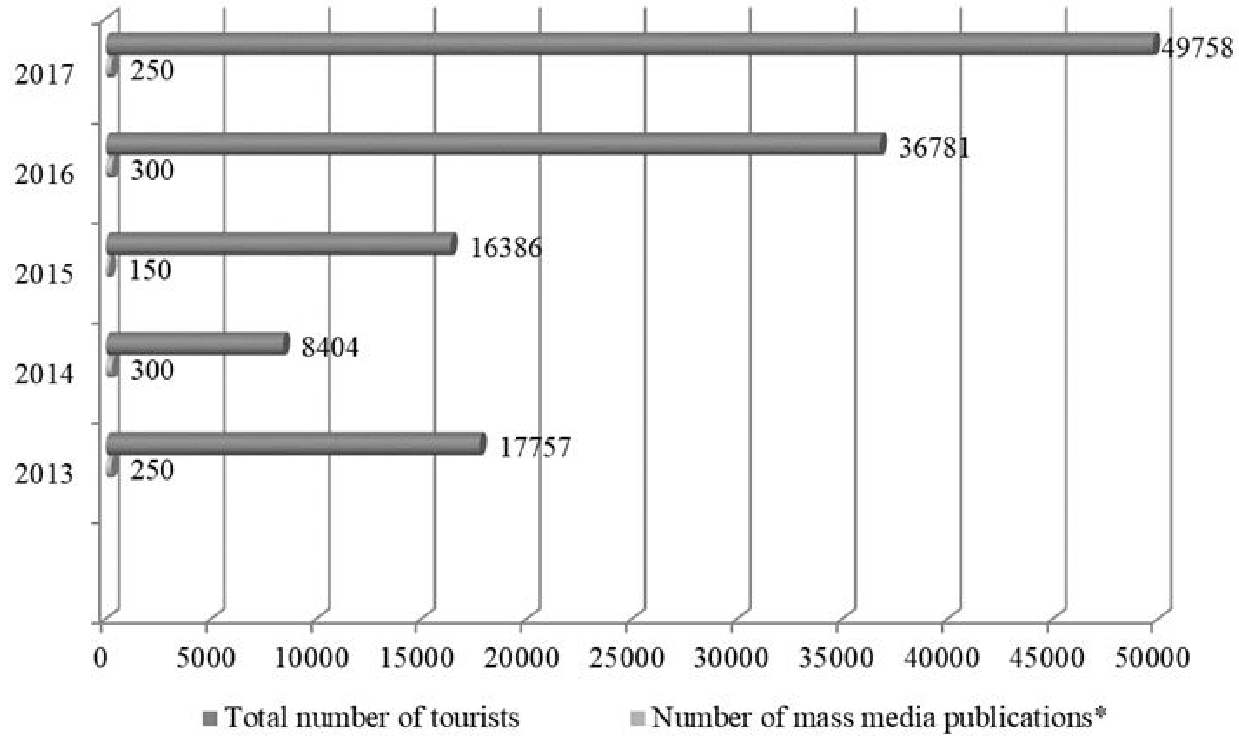

Fig. 2. Interconnection of the number of mass media publications and the number of tourists, units/persons
* materials describing the tourist experience of a journalist for the first 1,000 search queries in Google as of 27.07.2018
Authors' development

Discussion. According to our study, a trip to the CEZ requires from journalists such professional qualities as positive world perception;confidence in the absence of a threat to health; profound sense of professional duty; curiosity; impressionability; inclination to sensationalism; developed empathy; household unpretentiousness; imagination of thinking (Table).

The obtained results correlate with the results of research of professional psychological features of representatives of intellectual trades (Tolochek, 2005). According to them, high indicators of imagination of thinking (45%) and impressionability (36%) are explained by the personal qualities of journalists, such as inclination to abstract thinking, emotional sensitivity, sentimentality. At the same time, the focus of journalists on dark tourism can be explained by the breadth of views and radicalism.

The inclination to certain professional activities is explained by the psychotype of the employee (Pittenger, 1993). Journalists belong to the ENFR type - an individual of this type takes an active part in the lives of others, tries new types of activities, is not afraid of difficulties, is inclined to make decisions under the influence of emotions, can not live without dramas and shocks (Krups'kyj, 2015). These peculiarities of journalists are explain their developed empathy (compassion and sensitive perception of events), the ease of making a decision to travel to the CEZ. At the same time, the tragedy of the history and the gloomy appearance of the territory, the problems of its former and current residents make it attractive to journalists.

An interesting situation arises when a journalist seeks to get into the territory, and then he feels confused by the emotions. Personal interest explains the predominance of the voluntary motive of the trip (61.5%) over the forced (38.5%). In this case, the professional and personal components of the trip are balanced (by 38%): in addition to the curiosity and impressionability of ordinary tourists, journalists have a profound sense of professional duty and a inclination to sensationalism.

The professional interest of journalists in visits to the CEZ may be due to their inclination to risk. According to studies conducted by CareerCast, newspaper reporters take the 6th place in the top 10 most stressed professions by 2018 (after a military officer, firefighter, pilot, police officer, coordinator of events) (CareerCast, 2018). Among the causes of stress in this profession, in addition to the hardened deadlines and the fixed attention of society, researchers call the necessity to respond to unexpected risks. In addition, people at risk are more likely to smoke than those who are not at risk (Clifton et al., 2018). Meanwhile, 30% of male journalists are smokers, female journalists - 27% (Superjob, 2011).In addition, women are better able to assess the presence of risk in a particular situation, that is explained by their increased vulnerability in comparison with men (Bord, O'Connor, 1997). The impact of this factor on the decision to travel to the contaminated area can explain the results of our study: a slightly smaller number of women journalists in the CEZ (46% of women versus 54% of men) and a rather high level of confidence in the absence of a threat to health (55%).

Regulation of media tourism in the CEZ. Provision of tourist services is not provided in the territory of the CEZ. Therefore, from the legal point of view, it is expedient to use the term «visit» and not «tourism» (Derzhavne agentstvo Ukrai'ny z upravlinnja zonoju vidchuzhennja, 2016). This is due to the fact that coming and staying at the territory is limited, and staying without an official permit is prohibited. Hence, fears of public disregard for the provision of commercial services in a territory that was recently the center of a disaster confirms the concept that fear is an obstacle on the way to innovation (Rogers 1995; Hargadon, Douglas, 2001).

In spite of this, in the scientific opinion an approach to visits to the CEZ was formed just like for tourism (Pestushko, Chubuk, 2010; Yankovska G., Hannam K., 2014). During the 1990s, visitors to the territory were exclusively scientists and specialists of the consequences of the accident (Pestushko, Chubuk, 2010). That is why such visits can not be considered as tourism. The beginning of the the real tourism activity in the CEZ refers to 2000s, when in 2004 the first official tourist routes were developed.

It means that, despite the apparent development of tourism in the CEZ, the emotional bias that existing in the society does not allow recognize it officially. M. Voronov and R. Vince emphasize the inclinatioms of individuals to manifest emotions in response to certain aspects of institutions (Voronov, Vince, 2012), for example, legislative decisions. In this case, such negative aspect is the moral inadmissibility of speculation on the human sorrow.

In favor of asserting that journalists' visits to the CEZ are the media tourism, speaks the definition of business tourism to which it belongs. It emphasizes the connection of such trips with business activity: «Business tourism refers to journeys undertaken for work-related purposes» (Davidson, 1994). As our research has shown, despite certain natural limitations, connected with the peculiarity of the territory, the travels of journalists is conditioned by the fulfillment of the professional duties and are carried out within the framework of predrawn up routes. The precence of targeted travel services for journalists and the extensive experience of tourist companies as to their work with mass media in this area make it possible to classify in theory journalists' visits to CEZ as media tourism.

It is impossible to talk about official recognition and legislative consolidation of tourism in the CEZ at this stage. The adoption of such a decision requires the study of emotional obstacles to tourism activities in the CEZ and the realization of the ways on their elimination in practice.

The role of media presentation of the territory in promoting dark tourism. According to the founder of the «Chernobyl-tour», Ukraine receives

about $ 10 million annually from the inbound tourism in the CEZ (Lesiv, 2017). Under such conditions, the development of tourism in this area is of great comer-cial importance for Ukraine. From this point of view, the transformation of the CEZ from the tragedy zone into the development zone is the correct strategy for
economic growth in the country.

The research confirmed the great importance of the media presentation of the territory in the process of promoting dark tourism and creating its image. The growing influence of media and video games on the development of tourism experience is pointed out (Yankovska, Hannam, 2014). The image of the tourist area, designed by media such as films, television and literature, plays a significant role when choosing a place of rest (Ivashita, 2006). Media presentation affects the perception of tourists of a particular territory and country as a whole. Thus, through the media, it is possible consolidate, enhance and promote very effectively separate images, representations of tourist attractions and their attitudes towards them.
Moreover, media influence the formation of international tourist images (Butler, 1990).Motivational studies have confirmed that a source (media resource) with information about a tourist object can affect the desire of tourists to visit it. To form new objects their images are created and used in popular media. In addition, there is a link between the form of the media, the type of tourist and the characteristics of the object. That is, for the CEZ, own means of media promotion in accordance with specific features should be developed.
Connection of the development of media and dark tourism in the CEZ. The state should consider the role of the mass media in shaping tourist preferences, creating new tourist objects and their images in the minds of tourists in the development of tourism in the CEZ. Such cooperation is of great importance for promoting the region by enhancing its recognition, awareness and involvement of consumers. Insufficient information about tourist opportunities in the region leads to the impossibility of creating attractive image of the territory for potential tourists (Chulov, 2015). It means that the development of tourism in the CEZ is significantly dependent on the development of media tourism (Fig. 3).

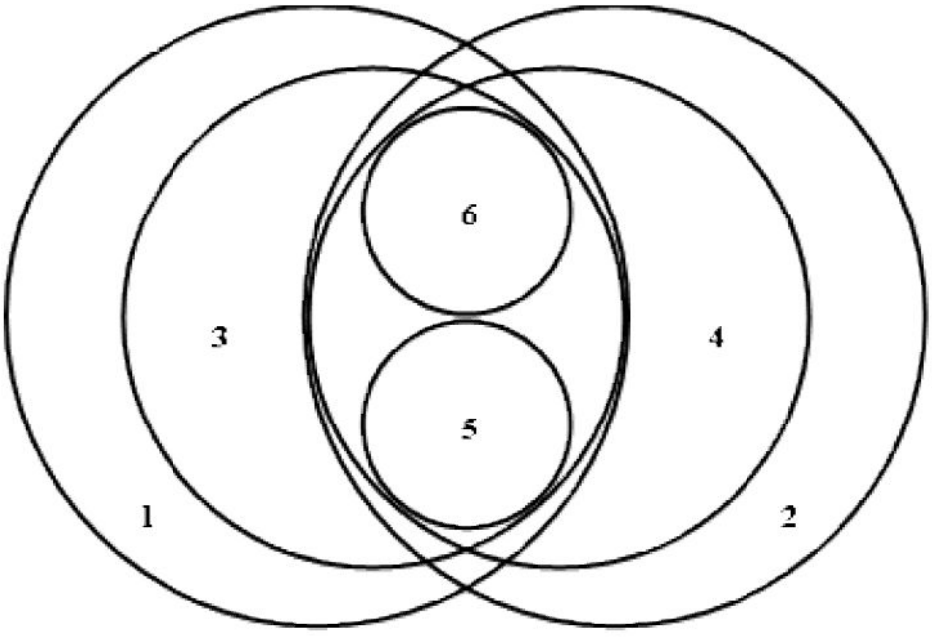

Fig. 3. Connection between dark and media tourism
1 – journalist activity; 2 - dark tourism; 3 - media tourism; 4 - tourism in the CEZ; 5 - editorial business trip; 6 - self-initiated trip
Author's development

Particular attention should be paid to cooperating with foreign mass media (BBC, Discovery, Lonely Planet), since the share of foreign tourists in the CEZ annually is about 70%, and their servicing is more profitable than servicing Ukrainians. According to official data, for the preparation of the program for the tourist group, the TISMCEZ receives 2000 UAH from foreign citizens, 495 UAH from the Ukrainian ones. The cost of one-day escort by the responsible person of the TISMCEZ of one foreign citizen is 500 UAH, Ukrainian - 140 UAH (Derzhavne agentstvo Ukraiʹny z upravlinnja zonoju vidchuzhennja, 2016). SAUEZM intends to send all tourism-related activities to the development of the tourist infrastructure of the CEZ: improvement of the territory (installation of toilets, tree trimming, garbage gathering, creation of cafes and other events) (Derzhavne agentstvo Ukrai'ny z upravlinnja zonoju vidchuzhennja, 2016).

It is necessary to continue developing a state strategy for coverage of the CEZ in the world mass media, which would contribute to the formation of a positive image of the territory and tourist preferences in this direction. One of the steps of this strategy is to formulate the essence of the brand: holding special bright cultural events, attracting attention to unusual historical values, monuments, facts, events, etc. (Smirnova, Privarnikova, 2015). It is expedient to develop special tourism programs, to conduct regular excursions and seminars for journalists, to cooperate with mass media on content production to attract tourists from their audience - documentaries and feature films, television special projects, and other media support tools. In addition, information about the region should be submitted in detail, emotionally, personally and regularly (Chulov, 2015).

Cultural aspect of media tourism in the CEZ. The local government should engage in public dialogue to explain the benefits of developing dark tourism and help it in the decision-making process (Kim, Butler, 2015). This work is of particular importance in the conditions of polarization of public opinion on the ethics of the development of such tourism, which took place in Snowtown (Southern Australia) (Kim, Butler, 2015). The overwhelming majority of local "long-livers" was against the exploitation of recent criminal events in the city to attract tourists. While other residents, especially those who arrived in the city after the arrest of the murderous killers in Snowtown (after 1999), supported this idea.In the Ukrainian society, there is also a problem of the ethics of such tourism in relation to the Chernobyl veterans and victims of the disaster. Also, despite the explanatory work, there are biases regarding the environmental and radiation hazards of the territory. The elimination of these obstacles can be achieved by dialogue with the public through the Ukrainian and world mass media.

It should take into account the attitude of journalists themselves to the development of dark tourism, which they cover and to which their publications contribute. The professional duty of journalists makes them cover all relevant social phenomena such as tourism in the CEZ even if it is harmful for their health. This allows them to work in the most unfavorable conditions - in any area where there is a risk or danger to health and life. This can also explain such a feature of journalists in the CEZ, as profound sense of professional duty (Table).

The feature of the CEZ is not only the personal attitude of the journalist to the work, but also his fear of his health after the trip. If the work at hot spots has a risk of injury or death, then work at the CEZ - the risk of radiation exposure in case of deviation from the route and violation of safety rules (Derzhavne agentstvo Ukrai'ny z upravlinnja zonoju vidchuzhennja, 2014). As our study showed, journalists have a confidence in the radioactive safety of the territory of the CEZ (Table). Professional characterological features allow them to ignore those aspects of information that can be perceived by others as negative. On the contrary, they have positive view of the phenomena they have to deal with in their professional activities. Such an attitude is one of the mechanisms of psychological protection in condi-tions of increased stress in the profession. Thus, the psychological peculiarities of world perception allow journalists to overcome successfully the specific barriers that distinguish the work of the CEZ from work in other territories.

Recommendations for future researchers. The research showed that the motivation for journalists' visits to the CEZ is business trip for covering newsbreak and looking for information as for publications on the state of the territory (including tourist routes). However, in the course of the study, the authors had a hypothesis about monetary reward as one of the main motivations of a journalist's visit to the CEZ. It needs to be checked in further research. To do this, it is necessary to create a database of journalists who visited the CEZ, indicating their contact details, and conduct questionnaires and interviews. Among other issues, it is necessary to develop the presence/absence of material incentives and rewards for such journalists for work in a radioactive contaminated area.

In order to solve the problem of the ethical aspect of media tourism, it is necessary during the interview to find out the personal attitude of journalists to performing such a kind of work. It should be taken into account, which part of those who visited the CEZ, felt internal discomfort before, during and after the trip. It is also necessary to determine how many journalists refused the proposed trip and for what reasons (fear for the state of health, ethical beliefs, etc.).

Conclusions. In our study, we were able to describe a new phenomenon of media tourism in the Chernobyl Exclusion Zone and to establish its peculiarities. Journalists traveling to the Chernobyl Exclusion Zone have specific personality traits. The most striking of them is confidence in the absence of risk, ability to empathize and imaginative thinking. Thus, the tragedy of history and the gloomy appearance of the territory, the suffering of its residents make it attractive for journalists. Personal interest explains the predominance of the voluntary motive of traveling over forced ones. Positive world perception and sense of professional duty allows journalists to ignore such features of the territory as the risk of radiation exposure and the problem of ethics. At the same time, the prevalence among them of male journalists is due to their lower ability to assess risk. The attention of journalists to the territory is attracted by the activity of tourists on it.There is a phenomenon of the so-called «compensation effect», when the reduction of tourists' attention to the territory is com-pensated by an increase in the attention of the mass media.

The organization of visits of journalists contributes to the formation of a positive image of the territory and the elimination of «information» pollu-tion. It is important to make cooperation with mass media a key element of the strategy of developing the tourist potential of this territory. At the same time, this work should be considered not only as an instrument of promotion, but also in terms of the prospects of media tourism. Further research will be devoted to the search for strategic directions for the promotion of media tourism in the Chernobyl Exclusion Zone.

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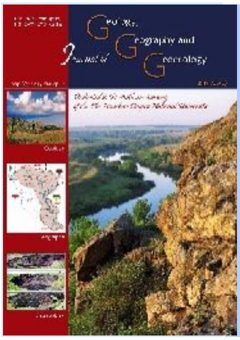

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GIS-based Assessment of the Assimilative Capacity of Rivers in Dnipropetrovsk Region

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Abstract. The objective of this paper is to identify the level of changes in the ecological status of surface reservoirs of Dnipropetrovsk region under the impact of anthropogenic factors and to find a rationale for the limit loads on aquatic ecosystems, based on a quantitative assessment of their assimilative capacity values using GIS-technologies.To characterize and evaluate economic activity in the river basins of Dnipropetrovsk region, the data of state statistical reporting by the form of 2-TP "Water resources management" of the State Agency for Water Resources of Ukraine were used. Parameters characterizing the assimilative capacity of water bodies were determined by taking into consideration the perennial average values of river runoff resources of the priority watercourses of Dnipropetrovsk region in the years with varying degrees of supply: with an average (50%), a low (75%) and a very low (95%) river water content. The main indicators characterizing the assimilative capacity of the water bodies of Dnipropetrovsk region are actual and necessary multiplicity of wastewater dilution, the limit to assimilative capacity of surface reservoirs, index of assimilative capacity utilization of river runoff resources of varying degrees of supply. A classification that characterizes the level of assimilative capacity utilization for water bodies is proposed. The level of assimilative capacity utilization of the Dnipro River in the reservoir areas, regardless of the degree of river runoff supply, is estimated as “allowable” . At 95% degree of river runoff supply, the level of assimilative capacity utilization of the Oril and Vovcha Rivers is characterized as “moderate”, the Samara River (after the confluence with the Vovcha River) as “high” and the Ingulets River with tributary the Saksagan River, and the Samara River (before confluence with the Vovcha River) as “very high”. It should be noted that irrespective of the level of river runoff supply, the index of assimilative capacity utilization of the Samara River (before its confluence with the Vovcha River) exceeds the limit value by 19-115 times. For the spatial analysis of hydrological parameters and visualizion of the data in the form of thematic maps, the geoinformation system “Rivers of Dnipropetrovsk region” was developed on the basis of the ESRI ArcGIS Desktop10 software package. Using the geoprocessing tools, on the basis of hydrological indices of 7 priority watercourses for each of the 22 administrative-territorial districts of Dnipropetrovsk region, the main indicators characterizing the assimilative capacity of water resources were calculated and ranked. The use of indicators characterizing the assimilative capacity of river runoff resources allows us to identify the threshold levels of anthropogenic transformation of aquatic ecosystems, develop and implement environmental measures to improve the ecological status and ensure environmental safety of surface reservoirs.

Key words: assimilative capacity,multiplicity of wastewater dilution, index of assimilative capacity utilization, river runoff, self-purification of water reservoirs

Оценка ассимиляционной емкости рек Днепропетровской области с использованием геоинформационных технологий

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Анотація. Проведено аналіз забору річкової води й скиду стічних вод у поверхневі водойми Дніпропетровщини. Визначено величини фактичної та необхідної для самоочищення кратності розведення стічних вод різної категорії якості річковими водами. Встановлено значення граничної асиміляційної ємності ресурсів річкового стоку Дніпропетровської області різного ступеня забезпеченості. Розраховано значення індексу використання асиміляційної ємності ресурсів річкового стоку різного ступеня забезпеченості. Запропоновано класифікацію, що характеризує рівень використання асиміляційної ємності водних об’єктів. Встановлено, що рівень використання асиміляційної ємності річки Дніпро на ділянці водоймищ незалежно від рівня забезпеченості річковим стоком, оцінюється як "припустимий". При 95%-вому ступені забезпеченості річковим стоком рівень використання асиміляційної ємності річок Оріль і Вовча характеризується як "помірний", р. Самари (після впадіння в неї р. Вовча) – "високий" та річок Інгулець з припливом Саксагань і Самара (до впадіння в неї р. Вовча) – "надзвичайно високий". За результатами розрахунків на основі програмного комплексу ESRI ArcGi Desktop10 розроблено геоінформаційну систему "Річки Дніпропетровської області". Визначено питомі показники, що характеризують асиміляційну ємність водних ресурсів у дуже маловодні роки за адміністративно-територіальними районами області.

Ключові слова: асиміляційна ємність, кратність розведення стічних вод, індекс використання асиміляційної ємності, забезпеченість річковим стоком, самоочищення водойм

Introduction. Intensive economic activity in the river basins of Dnipropetrovsk region significantly affects the quantitative and qualitative indicators of water resources and their ecological status. The overwhelming majority of Dnipropetrovsk region’s rivers are degraded, as a result of an excessive anthropogenic load, prevailing over the capacity of water bodies for self-purification and self-repair. This, in turn, is exacerbated by the low level of water supply of the region. The resources of local river runoff are very small and amount to 450 m^3 per 1 inhabitant (Regional report on the state of the environment in Dnipropetrovsk region in 2016, 2017).

Small and medium-sized rivers experience anthropogenic impact more acutely than large ones, due to their small water content , and as a rule, the worst purification of wastewater dischargedinto them . The river beds accept the main technogenic load from water-users. Today, human economic activity has led to a crisis situation in the small and medium-sized rivers of Dnipropetrovsk region, which to a large extent determine the overall state of the DniproRiver. The largest tributaries of the Dnipro are the rivers Oril, Samara with the tributary of Vovcha and the Ingulets with the tributary of Saksagan. These rivers are the main sources of water supply in Dnipropetrovsk region, so far as they have a constant water flow. To ensure of the ecological safety of surface reservoirs, it is necessary that the paces of water resources use caused by natural processes and anthropogenic impact correspond to the paces of resumption (restoration) of aquatic ecosystems within the framework of balanced water use.

The result of technogenic impact on rivers is the loss of capacity of aquatic ecosystems for natural self-purification and self-restoration, that is, to cause a decrease in their assimilative capacity (Cairns Jr., 1999; Fallah-Mehdipour, 2015). Assimilative capacity (potential) of an ecosystem is an indicator of the maximum dynamic capacity of the amount of pollutants which can be accumulated, destroyed, transformed and transferred beyond the volume of the ecosystem without disturbing its normal activity (Izrael, Tsyban, 1989).

One method used to normalize the ecological state of aquatic ecosystems is assessment their ability to purify themselves by calculating the assimilative capacity for each water body or part of its water area (Glasoe, Steiner, Budd, Young, 1990; Hoang Ngos, Tran Quang, 2012; Hernandez, Uddameri, 2013). Thus, the use of indicators characterizing the assimilative capacity of river runoff resources allows us to identify the threshold levels of anthropogenic transformation of aquatic ecosystems, develop and implement environmental measures to improve the ecological status and ensure environmental safety of surface reservoirs.

The objective of the paper is to identify the level of change in the ecological status of surface reservoirs of Dnipropetrovsk region under the impact of anthropogenic factors and to find a rationale for the limit loads on aquatic ecosystems, based on the quantitative assessment of their assimilative capacity values using GIS-technologies.

Materials and methods of research. To characterize and evaluate economic activity in Dnipropetrovsk region’s river basins, the data of state statistical reporting by the form of 2-TP "Water resources management" of the State Agency for Water Resources of Ukraine were used. To determine the limit assimilative capacity of water bodies, we used perennial average values of river runoff resources of the priority watercourses of Dnipropetrovsk region in the years with varying degrees of supply: with an average (50%), a low (75%) and a very low (95%) river water content.

As the main water bodies, for which the indicators characterizing their assimilative capacity were calculated, the largest watercourses of Dnipropetrovsk region were selected:

1 – the InguletsRiver, including its tributary the SaksaganRiver;

2 – the Dnipro River, site I (the area of the Dniprodzerzhinsk-Dnipro reservoirs);

3 – the OrilRiver;

4 – the Samara River, site I (before the confluence with the Vovcha River);

5 – the Samara River, site II (after the confluence with the Vovcha River);

6 – the VovchaRiver;

7 – the Dnipro River, site II (the area of the Dnipro-Kakhovka reservoirs).

Assimilative capacity of water bodies was assessed using the following groups of indicators:

1. Basic:

– total wastewater discharge into surface water bodies, mln. m^3;

– amount of wastewater discharged into water bodies as normatively clean (without purification), mln. m^3;

– amount of wastewater discharged into water bodies as normatively purified, mln. m^3;

– amount of wastewater discharged into water bodies as contaminated or insufficiently purified, mln. m^3;

– volume of river runoff the varying degrees of supply (in the years with an average, a low, a very low river water content), mln. m^3.

2. Estimated:

– value of necessary multiplicity of wastewater dilution discharged into surface reservoirs, conv. units;

– value of limit assimilative capacity of the water body that accepts discharged wastewater, mln. m^3;

– index of assimilative capacity utilization of the water body, conv. units.

The main criterion of assimilative potential of the water body is the multiplicity of wastewater dilution.

The indicator of necessary multiplicity dilution of wastewater volume in the water body volume is a universal characteristic (Farhadian, Bozorg Haddad, Seifollahi-Aghmiuni, Loáiciga, 2014; Monfared, Darmian, Snyder, Azizyan, Pirzadeh, Moghaddam, 2017). It shows by how many times the water volume that takes part in river runoff dilution increases relative to the primary discharged wastewater volume.

Depending on the ratio of the discharged wastewater volume and the water body volume, taking into account the intensity of dilution and self-cleaning processes occurring in it, various amounts of wastewater can be discharged into each water body for a certain time. At the same time, the limit volume of wastewater that can be discharged into a water body without violating sanitary requirements is conditioned by a certain dependence relative to water quality standards.

The natural self-cleaning ability of water bodies and watercourses is very low. A self-cleaning process occurs only if the wastewater is discharged into the surface reservoirs completely purified, and in a water body they have been diluted with river water in a ratio of 1:12-15. If, in water bodies and watercourses, wastewater is discharged in a large volume, and all the more so contaminated (or insufficiently purified), the stable natural balance of aquatic ecosystems is gradually lost, their normal functioning is disturbed, which makes these rivers unsuitable for use.

According to the recommendation of (Koronkevich, 1990), the multiplicity of dilution of conditionally pure water should be 1:3, purified household wastewaste – 1:5, unpurified – 1:20, purified industrial wastewaters – 1:15, unpurified – 1:50, for drains from urban territories – 1:3, from agricultural fields – 1:1. These values of the multiplicity of wastewater dilution were accepted as the basis for calculations.

For a more detailed study of the assimilative capacity of surface water bodies, various approaches and methods are used (Lee, Wen, 1996; Watson, Wyss, Booth, Sousa, 2012; Chiejine, Igboanugo, Ezemonye, 2016). Geoinformation technologies are the most important modern tool for analyzing data related to natural objects, which allow not only visualization of actual and forecasted situations on maps, but also generate new data and patterns. For example, the solution of tasks on the rational use and restoration of water resources can be carried out using automated GIS-zoning of study area (Rational Use and Recovery of Water Resources, 2016). For the assessment of levels of assimilative capacity utilization the rivers of Dnipropetrovsk region and visualization of data in the form of thematic maps, the geoinformation system “Rivers of Dnipropetrovsk region” was developed on the basis of the ESRI ArcGIS Desktop10 software package. To calculate and rank the indicators characterizing the assimilative capacity of water bodies, on the basis of hydrological indices of the seven priority rivers, geoprocessing tools such as overlay / identity were used for the administrative-territorial districts of Dnipropetrovsk region.

Results and their analysis. The main river of hydrographic networkofDnepropetrovsk region is the DniproRiver, which is represented by a cascade of reservoirs across the region territory: Dniprodzerzhinskoye, Dniprovskoye and Kakhovskoye. The total length of the DniproRiver within the region is 261 km, including 66 km within the Dniprodzerzhinskoye, 94 km within Dniprovskoye and 101 km within Kakhovskoye reservoirs.

In general, the hydrographic network of the Dnipro River basin within the region (Fig.1) is represented by 291 rivers, over 10 km long (of which 9 rivers are medium-sized), 101 reservoirs, 3,292 ponds and 1,129 lakes.

Currently, the water resources of Dnipropetrovsk region are intensively used for various needs. There are practically no rivers with a natural hydrological regime that has not been affected by economic activity. Most rivers are affected by the discharge of contaminated and/or insufficiently treated wastewater discharged by industrial, agricultural and communal enterprises directly into water bodies.

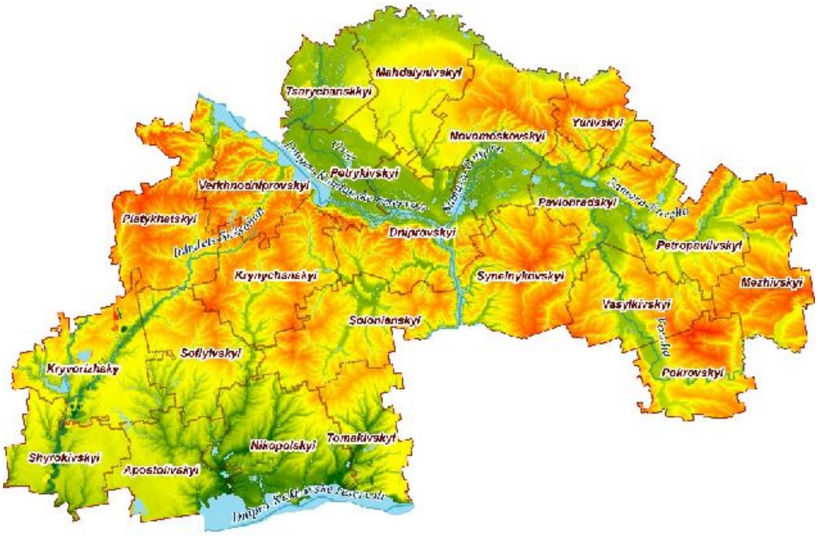


Fig. 1 Hydrographic network of Dnipropetrovsk region

The most important factors that affect the quantitative and qualitative indicators of water resources are the water intake from surface reservoirs and wastewater discharge of various quality categories.

Data about water intake from the considered surface reservoirs and the wastewater discharge of various quality categories in 2016 are provided in Table. 1.

Table 1 The values of water intake from surface reservoirs and wastewater discharge of various quality categories into water bodies of Dnipropetrovsk region

Sequence number of water body	Total water intake V_{intake}, mln. m^3	Total discharge V_{dis}, mln. m^3	Categories of wastewater discharged into surface reservoirs					
			Normatively clean without purification		Normatively purified		Contaminated (including insufficiently purified)	
			Discharge V_{NCWC}, mln. m^3	Share of total discharge K_{NCWC}	Discharge V_{NP}, mln. m^3	Share of total discharge K_{NP}	Discharge V_C, mln. m^3	Share of total discharge K_C
1. InguletsRiver	31.47	24.89	8.04	0.32	6.00	0.24	10.85	0.44
2.DniproRiver, site I	999.90	730.50	524.73	0.723	16.11	0.02	189.66	0.26
3.OrilRiver	7.06	5.00	0.44	0.09	-	-	4.56	0.91
4.SamaraRiver, site I	6.90	18.65	-	-	1.57	0.08	17.08	0.92
5.SamaraRiver, site II	11.18	27.25	1.63	0.06	23.45	0.86	2.16	0.08
6.VovchaRiver	33.99	2.59	-	-	1.05	0.41	1.54	0.59
7.DniproRiver, a site II	2261.59	878.88	715.50	0.81	99.20	0.11	64.18	0.07
Total:	3352.09	1687.76	1250.34	0.74	147.38	0.09	290.03	0.17

Most wastewater enters into surface reservoirs of Dnipropetrovsk region as contaminated or insufficiently purified. In the Oril and Samara rivers (before the confluence with the VovchaRiver), wastewater is completely discharged without purification. They account for 91% and 92% of the total wastewater discharge, respectively. Almost half the unpurified wastewater (44%) is discharged into the Ingulets River. The VovchaRiver collects 60% of the total discharge of contaminated wastewater. The remaining 40% of wastewater is discharged into the water body after purification. A significant amount of normatively purified wastewater (86% of the total discharge) enters the SamaraRiver after the confluence with the VovchaRiver.

Normally, in the structure of wastewater disposal in water bodies of Dnipropetrovsk region, normatively clean waters (without purification) predominate, which make up 74% of the total discharge. A significant part of normatively clean waters (72% and 81%) is discharged to the DniproRiver in the areas of reservoirs.

The share of normatively purified wastewater discharged into the surface reservoirs of the region makes up 9% of the total discharge, and contaminated including insufficiently purified – 17%. The percentage of wastewater discharged into water bodies of Dnipropetrovsk region after purification is rather low, which indicates a lack of interest of enterprises-water users in the implementation of environmental measures, including the installation of treatment facilities.

The level of river runoff use and the quality of water (or the intensity of contaminated wastewater entry into water ecosystems) over a certain period of time can be considered as integral indicators that determine the degree of anthropogenic load. The quality of water will depend on the volume of the water body. In this case, the anthropogenic load on water bodies is characterized by the coefficient of river runoff use K_{RRU}(Jacyk, Kanash, Stashuket al., 2007), which is estimated as the ratio of water intake from surface reservoirs (water intake coefficient) and the volume of discharged wastewater of various quality category to the value of river runoff at varying degrees of supply, that is,

$$K_{RRU} = \frac{V_{intake}}{V_{RR}} = \frac{V_{dis}}{V_{RR}}, \quad (1)$$

where V_{RR} is the volume of river runoff at varying degrees of supply for the main watercourses of Dniproopetrovsk region, which is given in Table 2.

Table 2. The volume of river runoff at varying degrees of supply for the main watercourses in Dnipropetrovsk region (Strelets, 1987)

Sequence number of water body	Supply the river runoff resources, mln. m^3, in the years with:		
	average river water content (50%)	low river water content (75%)	very low river water content (95%)
1. InguletsRiver	206	112	41
2.Dnipro River, site I	51100	42260	31670
3.OrilRiver	315	170	54
4.Samara River, site I	47	25	7,6
5.Samara River, site II	423	237	82
6.VovchaRiver	139	75	27
7.Dnipro River, site II	51100	42260	31670

The intensity characterization of anthropogenic load on water resources, depending on the cal-culated coefficient value of K_{RRU}, is given in Table 3.

Table 3. Estimated scale of anthropogenic load on water resources (Shiklomanov, 2008)

CoefficientvalueK_{RRU}	<10%	10-20%	20-40%	40-60%	>60
Intensity of anthropogenic load on water resources	low	moderate	high	very high	critically high

According to the "rule of one percent" (Reimers, 1990), aquatic ecosystems begin to lose their balance when fresh water is taken from water bodies and (or) contaminated wastewater is discharged, in the amount which exceeds 1% of river runoff value the varying degrees of supply.

It has been established (Jacyk, 2004) that when water resources are taken from surface reservoirs (wastewater discharge of various quality categories) in the volume of more than 10% of river runoff (K_{lim}<10%), the water body loses its capacity for self-purification.

The coefficient values of river runoff use the varying degrees of supply as a result of water intake from surface reservoirs in Dnipropetrovsk region and wastewater discharge of various quality categories are given in Table 4.

The water intake coefficient from the small and medium rivers of Dnipropetrovsk region in modern conditions reaches significant values. Thus, in the years with an average water content for the rivers Ingulets, Samara (before the confluence with the Vovcha River) and Vovcha River, it fluctuates within 15-25% of river runoff supply, which exceeds the limit permissible value by 1.5-2.5 times. In the years with very low water content, the values of water intake coefficient are even greater and makes up 77–126% of river runoff supply.

The most significant irrecoverable water costs are associated with excessive water intake for irrigation of agricultural lands, for watering vegetable gardens, garden areas, etc.

When calculating the coefficient of wastewater discharge into surface reservoirs of Dnipropetrovsk region, it is established that its values for the Ingulets and Samara Rivers not only exceed by 6 and 24.5 times, respectively, the limit permissible level of river runoff use in the years with a very low water content, but also for the Samara River (before the confluence with the Vovcha River) by 4 times more than the critical value of the coefficient (K_{CV}=60%).

Table 4. Results of calculating the coefficient values of river runoff use the varying degrees of supply for Dnipropetrovsk region

Sequence number of water body	The coefficient values of river runoff use (K_{RRU}), %					
	water intake coefficient in the years with:			coefficient of wastewater discharge in the years with:		
	average river water content (50%)	low river water content (75%)	very low river water content (95%)	average river water content (50%)	low river water content (75%)	very low river water content (95%)
1. InguletsRiver	15.3	28.1	76.8	12.1	22.2	60.7
2.DniproRiver, site I	2.0	2.4	3.2	1.4	1.7	2.3
3.OrilRiver	2.2	4.2	13.1	1.6	2.9	9.3
4.SamaraRiver, site I	14.7	27.6	90.8	39.7	74.6	245.4
5.SamaraRiver, site II	2.6	4.7	13.6	6.4	11.5	33.2
6.VovchaRiver	24.5	45.3	125.9	1.9	3.5	9.6
7.DniproRiver, site II	4.4	5.4	7.1	1.7	2.1	2.8

It is established that before the confluence of the VovchaRiver with the SamaraRiver, the volume of discharged contaminated and insufficiently purified wastewater, mainly mine waters, by 2.5 times exceeds the value of river runoff in the years with very low water content. This indicates that in the years with 95% level of river runoff supply, the Samara River in this area exists due to the discharged untreated wastewater. The river is practically unsuitable for any economic use and does not meet sanitary requirements (Kulikova, Pavlychenko, 2016).

Thus, excessive water intake from surface reservoirs and wastewater discharge leads to degradation of water bodies, loss of their ability to restore, deterioration of water supply conditions for the population living on the nearby area. Proceeding from this, to preserve the natural state of river ecosystems, it is expedient to control the specific load on water bodies.

Accounting the dilution capacity of the water body, which is based on hydrological data and its capacity for self-purification, allows us to determine the regime of wastewater discharge into the water basin and estimate the permissable amount of wastewater, that is, the critical ecological load. In this case, it takes into account the natural runoff of both the water body and wastewater.

The actual multiplicity of wastewater dilution of various quality categories (K_A) discharged into water bodies of Dniproopetrovsk region is determined by the formula:

$$K_A = \frac{V_{RR}}{V_{dis}}. \qquad (2)$$

The calculated coefficient values of K_A at varying degrees of river runoff supply are presented in Table 5.

Table 5. Results of calculating the multiplicity values of wastewater dilution discharged into surface reservoirs of Dnipropetrovsk region at varying degrees of river runoff supply

Sequence number of water body	Multiplicity of wastewater dilution of various quality categories:			
	actual (K_A) in the years with:			necessary (K_N)
	average river water content (50%)	low river water content (75%)	very low river water content (95%)	
1. InguletsRiver	8.3	4.5	1.7	1:26.381·V_{dis}
2.Dnipro River, site I	70.0	57.9	43.4	1:15.466·V_{dis}
3.OrilRiver	63.0	34.0	10.8	1:45.855·V_{dis}
4.Samara River, site I	2.5	1.3	0.4	1:47.057·V_{dis}
5.Samara River, site II	15.5	8.7	3.0	1:17.061·V_{dis}
6.VovchaRiver	53.6	28.9	10.4	1:35.794·V_{dis}
7.Dnipro River, site II	58.1	48.1	36.0	1:7.786·V_{dis}

Calculating the actual multiplicity values of wastewater dilution showed that, with the available wastewater volume discharge of various quality cat-egories, the Ingulets River, including its tributary the Saksagan River, and the Samara River do not have sufficient resources for dilution and self-purification processes. The worst situation is in years with very low river water content. At 95% level of river runoff supply of the SamaraRiver (before the confluence with the VolchyaRiver), the multiplicity value of wastewater dilution is 1:0.41, that is, the dilution process is not carried out.

Thus, due to excessive anthropogenic load, the resources of these rivers have completely lost their capacity for self-purification, since water bodies begin to experience the state of stress if the multiplicity of wastewater dilution with clean river water becomes lower than 1:10 (Reimers, 1990).

The actual multiplicity of wastewater dilution discharged into the remaining water bodies of Dnipropetrovsk region currently at least corresponds to the minimum that was previously taken to maintain the natural equilibrium of aquatic ecosystems (1:10).

Earlier, when the anthropogenic load on water bodies was insignificant, it was believed that to maintain the normal self-cleaning capacity of water basin, the multiplicity of wastewater dilution should be 1:10. However, today some wastewater requires more dilution with clean river water.

The most advanced treatment facilities provide for the purification of wastewater from organic pollutants by only 85-90%, and only in some cases – by 95%. Therefore, even after purification, it is necessary to dilute the treated wastewater with clean river water in a ratio by 1:6-12 and more for to ensure vital functions of aquatic ecosystems.

When calculating the necessary multiplicity of wastewater dilution (K_N) of various quality categories discharged into water bodies of Dnipropetrovsk region, the following ratios were adopted: for normatively clean waters (without purification) – 1:3, for normatively purified waters – 1:15, for contaminated (including insufficiently purified) – 1:50.

The necessary multiplicity value of wastewater dilution discharged into water bodies was determined by the formula:

$$K_N = \frac{3 \cdot V_{NCWC} + 15 \cdot V_{NP} + 50 \cdot V_C}{V_{dis}}. \quad (3)$$

The results of calculating the necessary multiplicity of wastewater dilution discharged into water bodies of Dnipropetrovsk region are shown in Table 5.

The calculated necessary multiplicity values of wastewater dilution allow us to determine how much the actual and theoretical values of this indicator really correspond to each other. At the present time, the actual multiplicity of wastewater dilution discharged into the Dnipro River on the reservoir areas, even in the years with a very low water content, exceeds the necessary values to ensure the normal functioning of reservoirs (by 2.8 times on the Dniprodzerzhinskoye – Dniprovskoye reservoirs and by 4.6 times – Dniprovskoye – Kakhovskoye reservoirs).

At wastewater discharge into the Oril, Vovcha and Samara Rivers (after the confluence with the Vovcha River), the actual multiplicity of wastewater dilution in the years with an average water content (50% level of river runoff supply) corresponds to the theoretically necessary value. At the same time, in the years with a very low water content, the coefficient values of K_F for all water bodies, except of the Dnipro River, is significantly lower than the necessary multiplicity of wastewater dilution.

Having determined the necessary multiplicity values of wastewater dilution K_N, we can find the value of limit assimilative capacity of the water body, which is expressed as the maximum amount of wastewater that can be discharged into the surface reservoir without violating its environmental sustainability.

The values of limit assimilative capacity of water bodies are defined as the ratio of the river runoff of varying degrees of supply to the previously calculated necessary multiplicity of wastewater dilution:

$$AC_{Lim} = \frac{V_{RR}}{K_N}, \text{ mln. m}^3. \quad (4)$$

The results of this calculation are presented in the Table 6.

Table 6. Calculation results of indicators characterizing the assimilative capacity of river runoff resources in Dnipropetrovsk region in the years with varying degrees of supply

Sequence number of water body	Limit assimilative capacity of water bodies (AC_{Lim}), mln. m^3, at the level of river runoff supply:			Reserve of river runoff resourcespotentially possible for use (V_{PPRR}), mln. m^3, at the level of supply:			The index of assimilative capacity of river runoff resources, conv. units, at the level of supply:		
	50%	75%	95%	50%	75%	95%	50%	75%	95%
1. InguletsRiver	7.81	4.25	1.55	-17.08	-20.64	-23.34	3.19	5.86	16.02
2.DniproRiver, site I	3303.92	2732.36	2047.66	2573.43	2001.87	1317.16	0.22	0.27	0.36
3.OrilRiver	6.87	3.71	1.18	1.87	-1.29	-3.82	0.73	1.35	4.24
4.SamaraRiver, site I	1.00	0.53	0.16	-17.65	-18.12	-18.49	18.67	35.12	115.12
5.SamaraRiver, site II	24.79	13.89	4.81	-2.45	-13.35	-22.44	1.10	1.96	5.67
6.VovchaRiver	3.88	2.10	0.75	1.29	-0.50	-1.84	0.67	1.24	3.44
7.DniproRiver, site II	6563.23	5427.83	4067.66	5684.35	4548.95	3188.78	0.13	0.16	0.22

As a result of calculation, limit values of assimilative capacity of the main watercourses of Dnipropetrovsk region are established, corresponding to the theoretical volume of wastewater that can be discharged into surface reservoirs without harm to water ecosystems. The basis of potential is the annual assimilative capacity of the Dnipro River, which is 2,000-6,500 mln. m^3 of wastewater.

Having determined the values of limit assimilative capacity of water bodies of Dnipropetrovsk region and the amount of water resources, which are being already in use and expressed by the actual volumes of wastewater discharge of various quality categories, it is possible to calculate the reserve values of river runoff resources potentially possible for use,

$$V_{PPRR} = AC_{Lim} - V_{dis}, \text{ mln. m}^3. \quad (5)$$

The results of calculating the reserves of river runoff resources potentially possible for use in the years with varying degrees of supply in Dniproopetrovsk region are presented in Table 6.

It is established that the reserve of potentially useable river runoff resources is fully exhausted. This means that the wastewater amount of various quality categories entering into the water bodies in Dnipropetrovsk region is greater than the maximum possible amount of wastewater that can be discharged into the surface reservoir without violating its environmental sustainability. The exception is the Dnipro River in the reservoir areas, which has significant reserves of river runoff resources potentially possible for use .

In the years with an average water content, the tributaries of the Dnipro River, namely the Oril and Vovcha Rivers, have an insignificant reserve of river runoff resources potentially possible for use.

The index of assimilative capacity utilization of river runoff resources at varying degrees of supply was determined from the ratio:

$$I_{ACU} = \frac{V_{dis}}{AC_{Lim}}, \text{ conv. units.} \quad (6)$$

The results of calculating the index of assimilative capacity utilization of river runoff resources at varying degrees of supply in Dnipropetrovsk region are given in Table 6.

The level of assimilative capacity utilization of river runoff resources from the values of I_{ACU} obtained was estimated in accordance with the proposed classification and presented in Table 7.

Table 7. Estimated scale level of assimilative capacity utilization of river runoff resources

Ranges of index values I_{ACU}	≤1	1-5	5-10	>10
Level characterization of assimilative capacity utilization of river runoff resources	allowable	moderate	high	extremely high

According to the results of calculations, it is established that the level of assimilative capacity utilization of the Dnipro River on the reservoir areas, regardless of the degree of river runoff supply, is estimated as “allowable”. In the years with an average water content (50%), the level of assimilative capacity utilization of the Oril and Vovcha Rivers is estimated as “moderate”, the Samara River (after the confluence with the Vovcha River) and the Ingulets River with the Saksagan tributary – “moderate”.

At 95% level of river runoff supply, the I_{ACU} index for the considered water bodies, except for the Dnipro River, exceeds the limit value (I_{ACU}=1). At the same time, the level of assimilative capacity utilization of the Oril and Vovcha Rivers is character-ized as “moderate”, the Samara River (after the con-fluence with the Vovcha River) as “high” and the In-gulets River with tributary the Saksagan River, and the Samara River (before confluence with the Vovcha River) as “very high”. It should be noted that irrespective of the level of river runoff supply, the index of assimilative capacity utilization of $I_{ACU}$for the Samara River (before the confluence with the Vovcha River) exceeds the limit value by 19-115 times.

Based on the results of calculations, thematic maps published in the form of the GIS “Rivers of Dnipropetrovsk region” in the ArcGIS-Online service were obtained (Fig. 2–4). Since in years with a very low water content in surface reservoirs, the demand for water has been increasing, and the sanitary and hygienic conditions of aquatic ecosystems have been deteriorating, the maps are developed for the period when the level of river runoff supply is 95%.

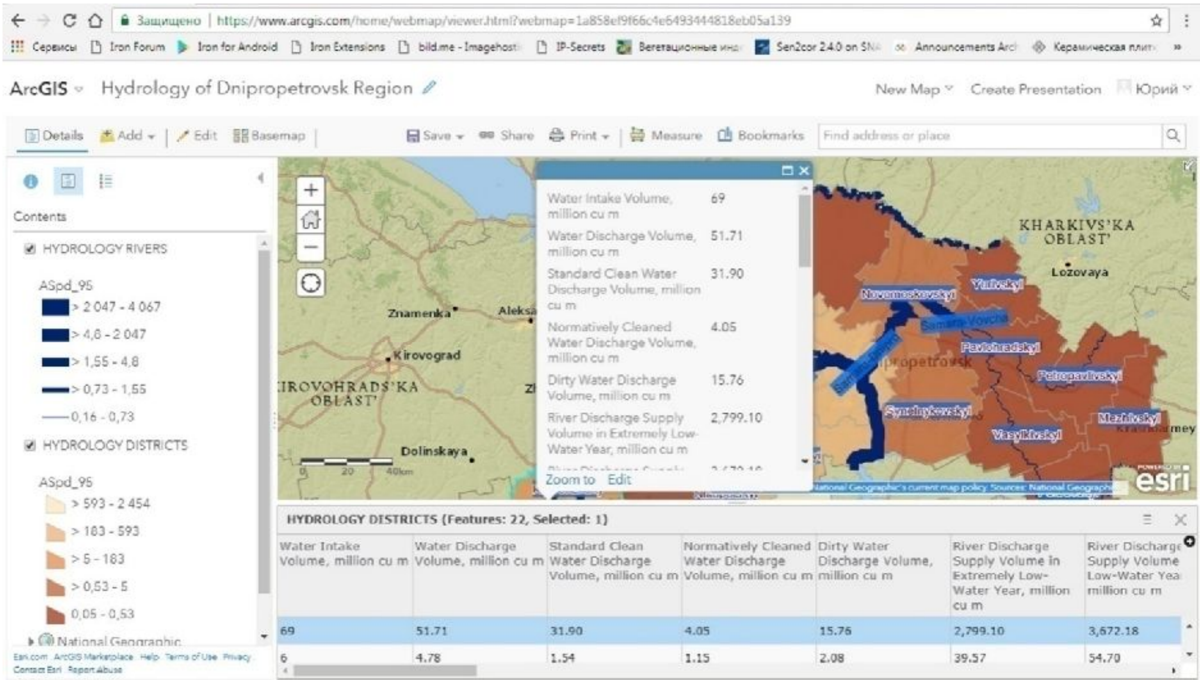
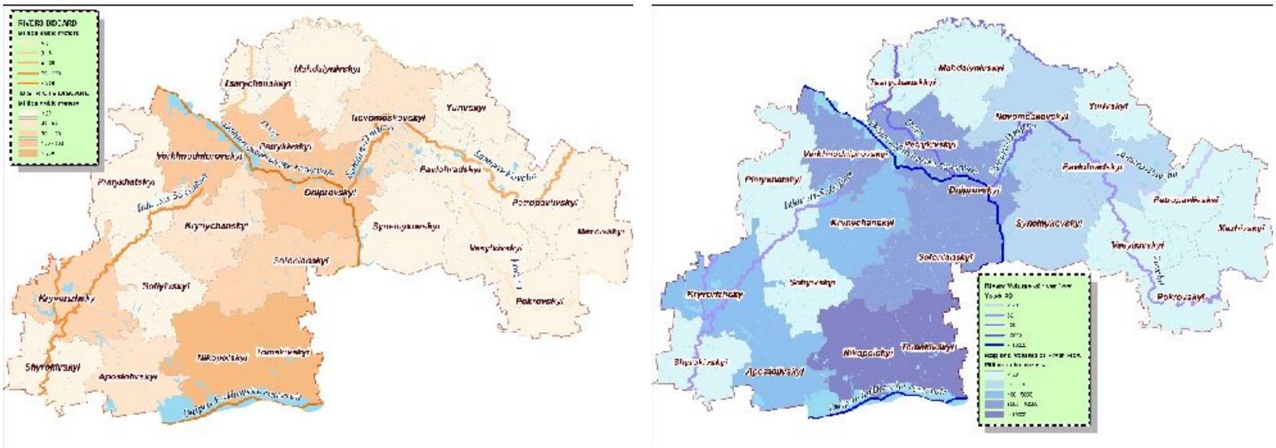
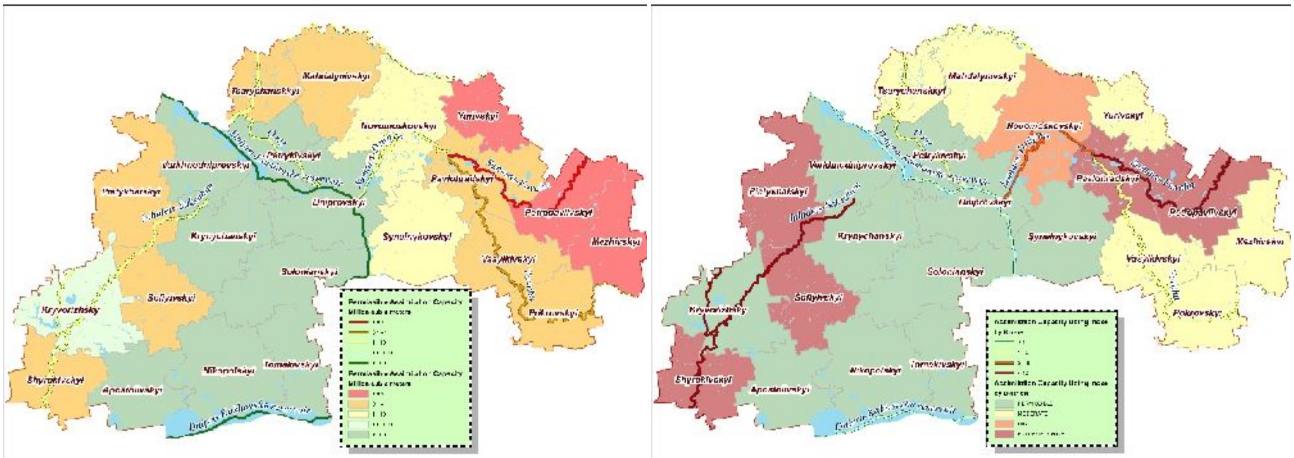


Fig. 2. Publication of the GIS "Rivers of Dnipropetrovsk region" in the ArcGIS-Online service



a) b)

Fig. 3. Distribution of total wastewater discharge (a) and river runoff supply in the years with a very low water content (b) over the area of Dnipropetrovsk region



a) b)

Fig. 4. Distribution of limit assimilative capacity (a) and index of assimilative capacity utilization of river runoff resources (b) in the years with a very low water content over the area of Dnipropetrovsk region

Using the geoprocessing tools, on the basis of the hydrological indices of 7 priority water-courses for each of the 22 administrative-territorial districts of Dnipropetrovsk region, the main indica-tors char-acterizing the assimilative capacity of water re-sources in the years with a very low river water content (95% level of river runoff supply) were calcu-lated and ranked per 1 inhabitant and unit area of a specific district. The results are pre-sented in Table 8.

Table 8 The main indicators characterizing the assimilative capacity of water resources in the years with a very low river water content over the area of Dnipropetrovsk region

Administrative-territorial district of Dnipropetrovsk region	Total wastewater discharge, m^3		River runoff supply, m^3		Multiplicity of wastewater dilution		Limit assimilative capac-ity of river runoff, m^3		tive ca-pacity utilization of river runoff
	e r l M	n h a	e r l M	i n h a b	c t u a	e s s	e r l M	i n h a b	
Apostolivskyi	0.0302	726.8	1.086	26168.38	36.0	7.8	0.1395	3360.98	0.22
Dniprovskyi	0.1218	2551.5	5.180	108480.73	42.5	15.6	0.3331	6975.21	0.37
Krynychanskyi	0.0237	1144.0	0.990	47737.80	41.8	15.9	0.0623	3005.78	0.38
Kryvorizhsky	0.0296	1153.4	0.967	37672.62	32.7	18.3	0.0529	2061.44	0.56
Mahdalynivskyi	0.0009	45.2	0.010	494.45	10.8	45.9	0.0002	12.06	4.2
Mezhivskyi	0.0002	8.6	0.002	90.18	10.4	35.8	0.0001	4.29	3.41
Nikopolskyi	0.2519	13190.1	9.075	475281.01	36.0	7.8	1.1655	61038.99	0.22
Novomoskovskyi	0.0099	273.4	0.032	889.05	3.2	17.9	0.0018	50.07	5.5
Pavlohradskyi	0.0080	450.8	0.013	737.97	1.6	38.2	0.0003	18.18	23.33
Petropavlivskyi	0.0082	396.5	0.003	161.69	0.4	47.1	0.0001	3.85	115.51
Petrykivskyi	0.1570	6572.4	6.776	283734.87	43.2	15.6	0.4332	18138.96	0.36
Piatykhatskyi	0.0018	67.2	0.003	109.77	1.6	26.4	0.0001	4.48	16.16
Pokrovskyi	0.0008	29.2	0.009	303.69	10.4	35.8	0.0002	8.76	3.44
Shyrokivskyi	0.0039	178.8	0.006	294.26	1.6	26.4	0.0002	11.17	16.04
Sofiyivskyi	0.0023	143.8	0.004	236.49	1.6	26.4	0.0001	9.27	16.05
Solonianskyi	0.0752	3396.4	3.261	147275.62	43.4	15.5	0.2108	9522.32	0.36
Synelnykovskyi	0.0011	50.2	0.049	2123.95	43.4	15.5	0.0031	137.37	0.37
Tomakivskyi	0.2552	12627.8	9.197	455083.01	36.0	7.8	1.1812	58444.43	0.22
Tsarychanskyi	0.0014	48.6	0.016	526.71	10.8	45.9	0.0003	11.21	4.23
Vasylkivskyi	0.0005	21.8	0.006	243.04	10.4	35.8	0.0002	6.23	3.21
Verkhnodniprovskyi	0.1401	3498.7	6.048	151037.28	43.2	15.5	0.3898	9735.65	0.36
Yurivskyi	0.0002	15.4	0.003	176.80	10.8	45.9	0.0001	7.69	3.99

The greatest amount of wastewater is dis-charged into surface reservoirs of Nikopolskyi, Tomakivskyi, Dniprovskyi, Verkhnodniprovskyi, Petrykivskyi and Solonianskyi districts. In accord-ance with (Ulzetueva, Gomboev, Zhamyanov, Mo-lotov, 2015), the intensity of anthropogenic load on the water bodies of these areas in terms of total wastewater discharge is estimated as “extremely high” (more than 100 mln. m^3 per year). In six dis-tricts of Dnipropetrovsk region (Kryvorizhsky, Krynychanskyi, Apostolivskyi, Novomoskovskyi, Pavlohradskyi and Petropavlivskyi), the intensity of anthropogenic load on water bodies is estimated as “high” (the volume of discharged wastewater is within $10<V_{dis}<100$ mln. m^3 per year), in three dis-tricts (Vasylkivskyi, Yurivskyi and Mezhivskyi) it is estimated as “low”. In other districts, the intensi-ty is characterized as “average”.

The most river runoff supply in years with very low water content was in 9 districts of Dnipro-petrovsk region (41% of the territory). In the most cases, the Dnipro River flows through these dis-tricts.

In ten districts of Dnipropetrovsk region (45.5% of the territory), the actual multiplicity of wastewater dilution discharged into surface reservoirs exceeded the necessary value by 1.8–4.6 times. This indicates that water bodies located in a given territory have a certain reserve of river runoff resources potentially possible for use.

Water bodies located on the territory of other areas (54.5% of the area of the region) do not have sufficient resources for wastewater dilution and self-purification processes. The actual multiplicity values of wastewater dilution do not correspond (much lower) than calculated values of necessary multiplicity of wastewater dilution. At the same time, in six districts of the region, the actual multiplicity values of wastewater dilution corresponds to the minimum ratio (1:10) necessary to maintain the natural capaity of water bodies for restoration.

In ten administrative-territorial districts of Dnipropetrovsk region (45.5% of the territory), the level of assimilative capacity utilization of river runoff in the years with a very low water content is estimated as “allowable”, in six (27.3%) as “moderate”, in one region (4.6%) as “high” and five districts (22.7%) as “extremely high”. The worst situation with assimilative capacity utilization of river runoff resources is in Piatykhatskyi, Shyrokivskyi, Sofiyivskyi, Pavlohradskyi and Petropavlivskyi districts. The index of assimilative capacity utilization of water bodies located in these territories exceeds the limit value (I_{ACU}=1) by 16-116 times.

Conclusions. 1. Rational use of water resources of small and medium-sized rivers is one of the complex and urgent problems in the water economy and management.Intake of river runoff resources, discharge of return waters into the watercourses, and various types of human activity in the river basin territories cause a decrease in the water capacity of the basins.

2. Loss of the capacity for self-purification, due to prolonged and excessive discharge of contaminated or insufficiently purified wastewater, will inevitably lead to contamination of aquatic ecosystems. The use of such water by the population for household, drinking or cultural and other purposes can lead to negative consequences for human health.

3. The limit assimilative capacity of the considered water bodies is in most cases exceeded. Therefore, one of the main tasks of sustainable water-use is to regularize the tempo of contaminated wastewater discharge toward the calculated value of assimilative capacity of aquatic ecosystems, the value of which will increase as the increase stable boundaries of anthropogenic load exceed.

4. The problem of rational use and protection of rivers should be solved in a comprehensive, systemic manner, taking into account the mutual influence of all factors, processes and components of the geographic network, as well as the impact of economic and other anthropogenic activities. In industrialized areas and in zones of intensive agricultural production (irrigation, animal husbandry), the purity of water resources, prevention of the discharge of contaminated or insufficiently purified wastewater into small water bodies are crucial in the problem of pollution of small and medium rivers. One of the main directions of work towards water resources protection is the complete purification of the wastewater formed, the implementation of new (low-water, non-water and non-waste) technological processes in industrial production, the transition to closed (in-line) water supply cycles, when the purified wastewater is not discharged but is utilized multifold in technological processes. Recycling and re-sequential water supply systems will make it possible to completely eliminate wastewater discharge into surface reservoirs, and use of fresh water to replenish irreversible losses.

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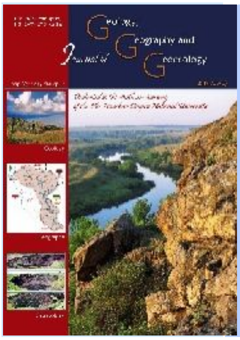

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Analysis of Territorial Differences of the Social Sphere elements in the Areas of the Carpathian-Podillia Region

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Abstract. The article is devoted to the problem of the social sphere functioning of the areas in the Carpathian-Podillia region, in particular the emphasis is placed on the differentiation of the levels of its individual components, the dynamics of their changes and the complex analysis of functionality. The state of this sphere directly influences the economy and culture of the country and the region, and therefore the sectors of education, health care, culture, housing and communal services, etc. play a significant role in the economic development of the territory. Territorial boundaries of the research are defined within Transcarpathian, Lviv, Ivano-Frankivsk, Chernivtsi, Vinnytsia, Khmelnytskyi and Ternopil regions, among which there are established economic, labor-resource and informational-communicative connections, which also should be considered as the strong side of such cooperation. Several basic components of the social sphere (education, culture, medicine, housing and communal services, trade and mass catering, communication) were selected for studying the differentiation of the social sphere elements of the areas of the Carpathian-Podillia region, for each several criteria were chosen (in general over 20). All suggested criteria represent a qualitative component of functioning: in education. They are the amount of preschool institutions for children, the number of pupils / listeners / students per number of inhabitants. Medical sphere includes the providing the population with doctors, middle medical personnel, hospital beds, planned capacity of outpatient clinics. The sphere of culture deals with the provision of population with cultural institutions and their attendance. The housing and communal services sector embraces the level of equipped apartments and indicator of residential space. Retail and catering services cover the indicators of trade turnover for main groups of goods and providing a decent number of trade areas, the field of communication includes access to communication facilities for different variants of their activity. This allowed analysing the level of formation and functionality of the social sphere individual components of the region in general and in its individual areas. On this basis, the ranking of the areas of the Carpathian-Podillia region was carried out in terms of the social infrastructure elements formation. In addition, a comparative analysis of the social sphere development level to the indicators of the Western Ukrainian region and Ukrainian is provided. Official statistics from the State Statistics Service of Ukraine, as well as regional statistical offices, were used for the survey.

Key words: Carpathian-Podillia region, geospatial organization, social sphere, education, culture, medicine, housing and communal services, trade and mass catering, communication, matrix of functioning level

Аналіз територіальних відмінностей елементів соціальної сфери областей Карпатсько-Подільського регіону

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Анотація. Стаття присвячена проблемі функціонування соціальної сфери областей Карпатсько-Подільського регіону, зокрема закцентовано увагу на диференціації рівнів окремих її компонентів, динаміці їх зміни та комплексному аналізу функціональності. Стан даної сфери безпосередньо впливає на економіку й культуру країни та регіону, а тому сектори освіти, охорони здоров'я, культури, житлово-комунального господарства тощо відіграє значну роль в господарському розвитку території. Територіальні межі дослідження визначені в межах Закарпатської, Львівської, Івано-Франківської, Чернівецької, Вінницької, Хмельницької та Тернопільської областей, між якими склалися усталені господарські, працересурсні та інформаційно-комунікативні зв'язки, які також варто вважати сильною стороною такої співпраці. Для дослідження диференціації елементів соціальної сфери областей Карпатсько-Подільського регіону було обрано кілька базових складових соціальної сфери (освіта, культура, медицина, житлово-комунальне господарство, торгівля і масове харчування, зв'язок), для кожної з яких було обрано кілька критеріїв (загалом їх понад 20). Це дозволило проаналізувати рівень сформованості та функціональності окремих складових соціальної сфери регіону загалом та в окремих його областях. На цій основі було проведено ранжування областей Карпатсько-Подільського регіону за рівнем сформованості елементів соціальної інфраструктури. Також подано порівняльний аналіз рівня розвитку соціальної сфери до показників Західноукраїнського регіону та пересічноукраїнських. Для проведення дослідження було використані офіційні статистичні дані Державної служби статистики України, а також обласних управлінь статистики.

Ключові слова: Карпатсько-Подільський регіон, геопросторова організація, соціальна сфера, освіта, культура, медицина, житлово-комунальне господарство, торгівля і масове харчування, зв'язок, матриця рівня функціонування.

Introduction. The modern stage of Ukrainian society development is oriented on social values that in the current environment reflects growing social weight of the creation of socially necessary product. The state of this sphere directly affects the economy and culture of the country; on this basis, one could claim that people engaged in education, health care, culture, housing and communal services etc. play a significant role in the economy. The example of the leading countries of the world shows that in addition to much attention to material production, a lot of effort are applied to priority social development, the prerequisites for social orientation of the economy are formed, to carry out state policy in the name of human as the main generator of civilization progress.

The problem of the development and functioning of the constituent elements of the social sphere is the research area of a large number of national and foreign scientists. V.I. Kutsenko and Y.V. Ostafiichuk consider the social sphere as a sphere of human activity, the result of which are services that meet the needs of society as well as individual members and are associated with the creation of added value (Kutsenko, Ostafiichuk, 2005). N.G. Pigul points out that the organizational mechanism for building a social sphere should be based on clearly defined functions, principles and tasks that will allow more effective implementation of the state social policy in order to improve the quality of life of the population (Pigul, 2013). Y. Oliinyk and A. Stepanenko consider the study of the social space of territorial communities and their social locality as an important direction in the study of social geography (Oliinyk, Stepanenko, 2012). L.M. Niemec considers the social sphere from the point of view of the spatial-temporal organization of society in terms of globalization influences; innovation-investment image of territories, model development and social-geographic zoning for optimization of the society territorial organization and ensuring optimal living conditions of the population, participation in the regions development of strategies (Niemec, 2003). We have also partially considered this problem when evaluating the employment of the Carpathian-Podillia region in the social sphere (Kuzyshyn, 2015a; Kuzyshyn, 2015b;Kuzyshyn, 2018).

With the increasing significance of the social sphere functioning, there is a need for a detailed analysis of the level of its components formation and the achievement of the complexity in providing the relevant services. The relevant issues seem to have the need to determine the current state of formation and demand of individual elements of the social sphere, as well as the level of their provision in a specific region, which allows determining its rating position in the region. To do this, we need to analyse a system of indicators that will allow us to form a comprehensive view of the social sphere of the Carpathian-Podillia region.

Purpose, task and methods of research. In preparation of this study, it was planned to determine, based on the analysing statistical information, the level of formation and functionality of the social sphere of the research region. For this purpose, statistical information was used over the period from the 90's of the twentieth century to 2016. This allowed to determine the trends of the functioning of the social sphere and its components.

To conduct research, we have selected a system of indicators, which served the criteria for evaluating certain elements of the social sphere – *educational sphere* (the coverage of children by preschool institutions; the number of students of comprehensive educational institutions per 10 thousand people; the number of students of vocational schools per 10 thousand people; the number of students of higher educational institutions with I-IV levels of accreditation per 10 thousand people), *cultural sphere* (availability of library funds per 100 people; availability of club membership per 100 people; attendance of museum institutions per 100 people; 8 – attendance of theatres per 100 people; 9 – attendance of concert events per 100 people), *sphere of health care* (availability of doctors per 10 thousand people; availability of average medical personnel per 10 thousand people;availability of hospital beds per 10 thousand people; planned capacity of outpatient clinics per 10 thousand people), *housing and communal services* (availability of housing space; an indicator of the level of private houses), *trade and mass catering* (availability of trade areas, retail turnover of enterprises per person (thousand UAH), retail sale of alcoholic beverages per person (l)), *connection* (number of subscribers of mobile communication; number of cable connection subscribers; the share of households having access to the Internet. It should be emphasized that they allow to evaluate the functionality of certain elements not from the point of view of quantity, but quality - provision, availability, demand of a certain social sphere element, which, in our opinion, reflect the real state of formation of the social sphere and makes it possible to differentiate its components according to the level of functionality formation.

In the process of research, the method of clusterisation was used. On the basis of the qualitative indicators analysis characterizing the social sphere of the areas of the Carpathian-Podillia region, a hierarchical cluster analysis was carried out with the subsequent construction of the dendrogram (using the Euclidean distance at clusterization).

Presentation of the main material. Territorial boundaries of the research are defined within Transcarpathian, Lviv, Ivano-Frankivsk, Chernivtsi, Vinnytsia, Khmelnytskyi and Ternopil regions (the area covers 19.1% of the territory of Ukraine and is home to 23.5% of the country's population). These areas have a compact location, which positively affects their cooperation and high interdependence. Sufficiently well-established business, labour, information and communication should also be considered as the strong side of such cooperation. However, historically, these territories were formed not as one, because in different historical periods they were part of various state institutions. To a certain extent, such territorial attachment also affected the ethnic composition of the population in the mentioned areas, which can be defined as diverse.

Consideration of social sphere elements should be carried out in the sectorial version of the assessment, but taking into consideration a certain territorial level.

The level of social sphere development is determined by the demand for services, and those, in their turn, vary according to the real possibilities of society at one or another stage of development. In today's conditions of an unstable economic situation in the country, the demand for many types of services has decreased due to low profits of the population, although there is an increase in interest in certain types of services (information, advertising, including tourism, health care, etc.).

The social sphere has certain territorial differences in the level of development and structure. Significantly higher level of its development and a wider sectorial structure is in cities compared to rural areas, in more economically developed industrial regions than in less developed agricultural areas.

The educational sphere is an important element in the formation of the social environment, the formation of an enlightened society and is a prerequisite for the preservation of intellectual society. Important indicators that characterize this area of the social sphere are qualitative characteristics of the educational space of the study area, for example, the coverage of children by preschool institutions, the number of students in general education institutions per 10 thousand people, the number of students of vocational schools , the number of higher education institutions students of I-IV accreditation levels per 10 thousand people. Such indicators allow us to assess the state of the educational environment in the research area. During 1995-2016, in the areas of the Carpathian-Podillia region, the rate of coverage of children in preschool institutions increased (from 31 preschoolers / 100 children of the corresponding age in 1995 to 62 preschoolers / 100 children of the corresponding age in 2016), which even exceeded the average Ukrainian index starting from 2010 (*Statistical Collection «Regions of Ukraine», 2017. Part 1).*Higher level of security is characteristic of the Podilsk regions. From 1995/1996 academic year up to 2013/2014 the number of students of comprehensive educational institutions in the amount of 10 thousand people decreased (from 1464 to 1039 students per 10 thousand population) and only during 2016/2017 academic year there was a tendency for an increase in the number of students in accordance to the number of residents (1067 students per 10 thousand population). It should be noted that this indicator has more positive numbers than the average in Ukraine. Over the period of 2000-2016 there was a decrease in the number of students of vocational education institutions per 10 thousand people from 104 to 81 students (but it is worth mentioning that these indicators are more positive than in Ukraine in general). The highest indicator is characteristic of the Lviv region (in 2016 - 107 students of vocational schools per 10 thousand people). As to the indicator of the number of higher educational institutions students in the Carpathian-Podillia region there was an increase in the number of students per 10 thousand people from 2000/2001 academic year to 2005/2006 academic year, but in subsequent academic years their number decreased faster than in Ukraine in general (*Statistical Collection «Regions of Ukraine», 2017. Part 1).*

When evaluating the educational sphere according to the criteria chosen by us, the matrix table confirms that the most developed this sphere is in the Lviv region, and the indicators of the educational environment functioning in the Vinnytsia, Ternopil and Chernivtsi regions are also high, while in other areas of the region there are problems with the separate components of the estimation of availability development of the educational sphere, or generally low efficiency of their functioning (Table 1). Compared with the average Ukrainian indicators and indicators characteristic to all areas of the Western Ukrainian region. In this territory there were always higher indicators of coverage of children by preschool institutions, the highest number of pupils and students in general education and vocational schools. Only a reduction in the number of students in higher educa-tion institutions in the region is higher than in Ukraine in general (this can be justified by the outflow of students to European, first and foremost, Polish educational institutions).

Culture covers institutions and establishments that produce cultural goods, offer spiritual values to the population etc. (libraries, theatres, clubs, museums, film studios, television, radio, newspaper and magazine publishing houses). Their placement is also associated with the peculiarities of people's resettlement: there is the higher concentration of cultural objects in large populations settlements. In the areas of the Carpathian-Podillia region there are over 5,7 thousand libraries, 6,4 thousand club facilities and cultural buildings (*Statistical Collection «Regions of Ukraine», 2017. Part 1).*They are placed according to the administrative division (in settlements – centres of administrative-territorial units, in urban microdistricts) and on a production principle – on the basis of enterprises, educational institutions, etc. For our analysis, we selected two areas – the availability of these institutions, which were evaluated through the index of availability of certain institutions for population and the population attendance of cultural and art establishments.

The indicator of the availability of cultural institutions, in particular library funds and club facilities in the Carpathian-Podillia region, is higher than the average in Ukraine and in the Western Ukrainian region in general. Although since 2000 these figures are decreasing in Ukraine, the decline rate in the region under study is not so significant. Thus, the average indicator of the availability of library funds in the region comprises 688 copies per 100 people, and in most regions (Vinnytsia, Lviv, Ternopil, Khmelnytskyi) it exceeds 700. If on average in Ukraine the provision of places in clubs is 10 places per 100 people, in this region it exceeds 15 (in Ternopil and Khmelnytskyi regions – 18).

Among the museum establishments of the Carpathian-Podillia region (161 establishments, almost 28 % of the total Ukrainian indicator) dominate regional history, historical, memorial museums. Most of them are situated in regional centres (the leader is Lviv), and among the regions as a whole the leader is Ternopil region – 30. The rate of attendance of museums in the regions of the area is higher (in 2016 – 46 visits per 100 people) than in Ukraine in general (37 visits per 100 people) and continues to grow. Higher indicators from the average regional rate were recorded in Transcarpathian and Lviv regions (48 and 75 visits per 100 inhabitants), the lowest – in Chernivtsi (31 visits per 100 inhabitants) (*Statistical Yearbook of Ukraine for 2016, 2017. Kyiv, 2017*). The reason for such a significant ampli-tude can be both quantitative indicators of museums as well as the practical interest of tourists and recre-ationists to this form of rest.

The largest number of professional theatres is in the Lviv region (9 out of 112, which operate in Ukraine). There are 27 professional theatres in the region in general. Regarding attendance, despite the established stereotype that the population of western Ukraine are theatre fans, the indicators are lower than in Ukraine – 11 visits per 100 inhabitants (with the exception of the Lviv region – 18 visits per 100 inhabitants) (*Statistical Yearbook of Ukraine for 2016, 2017. Kyiv, 2017*). It should be noted that this indicator includes a significant tourist component, because many Ukrainian and foreign tourists consider it mandatory to visit theatres during their travel programs.

Assessing the level of functioning of the cultural sphere components, it should be noted that their highest level is characteristic of the Lviv and Khmelnytskyi regions, high and relatively balanced - in Vinnytsia and Ternopil regions. If we analyse the dynamics of individual indicators, then from 2000 to 2016 in the areas of the Carpathian-Podillia region there is a deterioration and lagging behind the average Ukrainian indicator and indicator of the Western Ukrainian region in general regarding the availability of library funds, but there is an increase in the availability of places in clubs, there is an interest in visiting museums and the attendance of theatrical at concert events decreases.

The health-improving complex includes a system of medical and recreational institutions that provide health care (disease prevention, treatment), health improvement and recreation. There are 50000 doctors of all specialties in the healthcare institutions within the region (almost 27 % of the total Ukrainian indicator) and more than 100 thousand of medical staff (more than 27 % of the total Ukrainian indicator). The availability of doctors in the region under study is one of the highest in the country, but the percentage of sick people is constantly increasing due to unfavourable living conditions, inappropriate nutrition, and so on. Thus, from 2000 to 2016, the availability of doctors per 10 people in the Carpathian-Podillia region ranges from 45 to 50 specialists (in Ukraine this figure is significantly lower). The indicator of the availability of average medical personnel is also at the high level (more than 100 per 1 thousand population) as well as the amount of hospital beds (more than 77 per 10 thousand population). The highest rates are characteristic for Ivano-Frankivsk, Lviv and Ternopil regions.

The situation with the planned capacity of outpatient clinics is quite tense (all medical institutions conducting an outpatient appointment – outpatient clinics, out-patient departments, clinics, outpatient departments of hospitals, medical health centres, etc.). The situation improves since 2010, but lags behind the all-Ukrainian indicators. Only in two regions of the area (Vinnytsia and Transcarpathian) the planned capacity of outpatient clinics is higher than the average in Ukraine.

The medical field, according to selected criteria, has the highest index of availability of doctors, average medical personnel in the Ivano-Frankivsk, Lviv and Ternopil regions. Quite qualitative medicine can function in the Khmelnytskyi region. In other regions, the rating positions of the medical sector are rather low and, accordingly, indicate the problem of its development.

Housing and communal services satisfy the needs of people in housing, provide functioning of dwelling houses, hotels, small enterprises and institutions. This direction of the social sphere provides maintenance and repair of the housing stock and communal infrastructure. The entire housing fund in the Carpathian-Podillia region comprises 256 million square meters, which is more than 26 % of the state's housing stock. The city housing stock has a higher level of gas, hot and cold water supply, and sewerage than in the rural areas. Within the studied region, the main residential areas are concentrated in rural areas (more than 55 % of the total regional index). Today, in order to improve the living conditions of the population, considerable attention is paid to the development of investment (at the expense of private costs of individuals and legal entities) and individual housing construction. The average availability of housing stock in the region is higher (25.8 m^2 / person) than in Ukraine in general (22.9 m^2 / person). Among the areas of the region, the highest level of housing availability is characteristic of Vinnytsia (almost 30 m^2 / person) and Khmelnytskyi region (27 m^2 / person), the lowest is in the Lviv region (23 m^2 / person).

Communal infrastructure is an integral part of residential and household needs of the population and enterprises. It covers electricity, heat supply, gas supply, water supply, sewage, improvement and sanitary cleaning of the territory. Among indicators that characterize the arrangement of apartments in the Carpathian-Podillia region, the indicators of natural gas supply, sewage and centralized water supply are the highest. According to the index of natural gas supply, the highest indicator is characteristic of Ternopil, Chernivtsi and Khmelnytskyi regions (in all, over 93 % of the total regional indicator). The best water supply is typical for Lviv and Ternopil regions, sewage services and hot water supply – for the same areas. Centralized heating is best arranged in Ternopil and Khmelnytskyi regions.

With a consolidated assessment of the indicators that ensure the quality of the housing and communal complex functioning of these territories, the ranking of the highest positions are typical for the Ternopil and Khmelnytskyi regions, while Lviv, Ivano-Frankivsk and Vinnytsia regions are close to the average.

Trade and catering include retailers and mass caterers.

The most comfortable conditions for trade according to the trade space are noticeable in Lviv and Ivano-Frankivsk regions, high enough in Ternopil, Khmelnytskyi and Transcarpathian regions.

In the total volume of commodity circulation, groceries make up 65 %, non-food products – 35 %. The highest indicators of retail turnover per person is in Lviv region (13,5 thousand UAH / person, the indicator exceeds the average Ukrainian), and the lowest - in Ternopil region (7,6 thousand UAH / person). In addition to the traditional enterprises of the industry, a network of specialized stores, fast food catering establishments develope. An interesting indicator is the consumption of alcoholic beverages (in the calculation of pure alcohol l liter per person, this criterion is an applicator of the social structure level in the regions), according t which the minimum indices are characteristic for predominantly Podilsk regions (Vinnytsia and Ternopil – within 1.3 l / person) , and the maximum – for the Lviv region – 2,7 l / person.

According to the indicators characterizing the trade sector and mass catering, it can be noted that there is a very small amplitude between the regions, which allows us to assert the practically same level of functioning of the trading sphere.

Communication as a branch of economy consists of enterprises, lines and nodes, which provide the process of transmitting information over a distance (ie, telecommunication). This includes communication departments, telephone and telegraph stations, post office, radio broadcasting, television, etc.

From the beginning of the XXI century along with the media (radio and television), an individual connection is developing extremely fast. At the same time, its traditional form – phone connection – is improving, interlacing with other types (satellite, radio). Another group of the latest telecommunication facilities widely uses video equipment and computers. This is telefax, e-mail, Skype, etc.

Due to accessibility to new forms and types of communication, there is a significant difference in the background of the regions. For example, Lviv region is the leader. Transcarpathian and Vinnytsia regions have rather high index characteristics as well. If one is to estimate the region's share of the indicator of the mobile subscribers number or the number of cable television subscribers, it is slightly more than 10 %, which corresponds to the correlation index of the population share in the Ukrainian index.

On the basis of the conducted component analysis, it is possible to rank the regions of the Carpathian-Podillia region in terms of the functioning of the elements of the social sphere. The method of clusterisation analysis was used to conduct the research, which allowed to analyse the state of functioning and differentiation of the level of social sphere elements in the context of the mentioned administrative units.

For the characteristics of each social sphere element of the region there is a corresponding rank (from 1 to 7), according to the indicator occupied by the region (the rank is higher, provided that it has the higher corresponding absolute index). Fewer points provide a better ranking.

Several blocks of criteria were used during the formation of matrix. They were grouped into: *educational sphere*: 1 – the coverage of children by preschool institutions; 2 – number of students of comprehensive educational institutions per 10 thousand people; 3 – the number of students of vocational schools per 10 thousand people; 4 – the number of students of higher educational institutions with I-IV levels of accreditation per 10 thousand people; *cultural sphere*: 5 – availability of library funds per 100 people; 6 – availability of club membership per 100 people; 7– attendance of museum institutions per 100 people; 8 – attendance of theatres per 100 people; 9 – attendance of concert events per 100 people; *sphere of health care*: 10 – availability of doctors per 10 thousand people; 11 – availability of average medical personnel per 10 thousand people; 12 – availability of hospital beds per 10 thousand people; 13 – planned capacity of outpatient clinics per 10 thousand people; *housing and communal services*: 14 – availability of housing space; 15 – an indicator of the level of private houses; *trade and mass catering*: 16 – availability of trade areas, 17 – retail turnover of enterprises per person (thousand UAH); 18 – retail of alcoholic beverages per person (l); *connection*: 19 – number of subscribers of mobile communication; 20 – number of cable connection subscribers; 21 – the share of households having access to the Internet.

Table 1. RankingofpartsofCarpathian-Podilliaregionaccording to the level of social sphere elements formation, indexes of 2016*

Regions	*Criteria for evaluation / rank*																						
	Educa-tional sphere				*Cultural sphere*					*Medical sphere*				*Housing and com-munal services*		*Trade and mass catering*			*Communi-cation*			*Combined ranking of the region*	
	1	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*	*13*	*14*	*15*	*16*	*17*	*18*	*19*	*20*	*21*	*total*	*rank*
Vinnytsia	1	7	2	4	1	2	3	6	5	6	6	6	2	1	5	7	6	1	2	1	6	80	4
Transcarpathian	4	1	6	7	7	6	2	4	2	7	7	7	1	6	4	5	2	3	3	3	1	88	6
Ivano-Frankivsk	6	2	5	5	5	4	5	4	7	1	1	4	6	3	3	2	5	2	2	6	4	82	5
Lviv	5	4	1	1	4	5	1	1	1	3	3	1	5	7	2	1	1	6	1	2	3	58	1
Ternopil	3	5	3	2	3	3	3	3	6	4	2	2	4	4	1	3	7	2	6	4	5	75	2
Khmelnytskyi	1	6	4	6	2	1	4	3	3	5	4	3	3	2	3	4	4	4	5	5	7	79	3
Chernivtsi	2	3	5	3	6	4	6	5	4	2	5	5	7	5	6	6	3	5	4	7	2	95	7

* *Calculated forStatistical Collection «Regions of Ukraine», 2017. Part 1; Statistical Collection «Regions of Ukraine», 2017. Part 2; Statistical Yearbook of Ukraine for 2016, 2017.*

As a result of the analysis, the method of clusterization was used through multivariate statistical analysis. On the basis of indicators generalization of blocks-criteria, an algorithm for assessing the functioning of the social sphere of the areas of the Carpathian-Podillia region was formed:

1) the initial mass of information was analysed according to the indicators, which can be considered as two sub-masses - indicators-stimulators and indicators-destimulators;

2) for each of the six groups of indicators, the actual ranking is performed on the basis of absolute indicators, which are given in *Statistical Collection «Regions of Ukraine», 2017. Part 1; Statistical Collection «Regions of Ukraine», 2017. Part 2; Statistical Yearbook of Ukraine for 2016, 2017*;

3) for each region, a certain amount of rating indicators is determined, which demonstrate its own quantitative assessment of the social functionality in the regions according to the factors of stimulation;

4) in the format of a graph-tree, one can demonstrate the distribution of regional areas according to the level of social sphere formation and functionality;

5) the suggested meaning assessment of the final regions grouping according to the indicators of the functioning of the social sphere.

This methodological approach to qualitative rating indicators allows us to form a cohe-rent picture of the problem and to evaluate the social sphere functioning of the areas of the re-gion under study. It shows satisfactory results provided that there is a significant amount of evidence in the output masses of information (in our case more than 20 indicators) and their statistical homogeneity and equilibrium.

On the basis of the analysis, one can see (Fig. 1) that the most balanced social sphere functions in Lviv region. This is due to the balanced organization of the educational sphere at the level of preschool, general and higher education, the cultural sphere, which is monitored due to the demand of cultural institutions and their updating, the sphere of trade and mass catering that ensure the availability of food products and services for the local population and tourists, as well as communication (using of new and existing forms of communication by population) - these indicators provided the leading position of the region.

The general picture of the assessment shows that the majority of regions (Vinnytsia, Transcarpathian, Ivano-Frankivsk, Ternopil, Khmelnytskyi) have similar indicators of social development, but each of them often has its own advantages in the development of the social sphere elements. This does not allow to assert a balanced functioning level of the social sphere within these territories. Thus, for Vinnytsia region, there is the domination of education, culture, housing and communal services and communications in the social sphere, but the low level of functioning of the medical staff sector and trade. Transcarpathian region is characterized by formation and demand of the sphere of communication and trade, and other areas of social sphere are rather problematic. Ivano-Frankivsk region has a sufficient level of functioning of medical services, housing and communal services and trade. Ternopil region shows balanced functioning of the components of the educational sphere, culture, medicine, housing and communal services. Khmelnytskyi region is marked by formation and functioning of the sphere of culture, medicine, housing and communal services. As for the Chernivtsi region, in comparison with other regions of the Carpathian-Podillia region, this region has only high level in the sphere of education, while in the other groups of indicators there are unbalanced and low indicators. The suggested clustering of the regions of the research area (Figure 1) shows their place according to the balance indicators of the social sphere functioning.

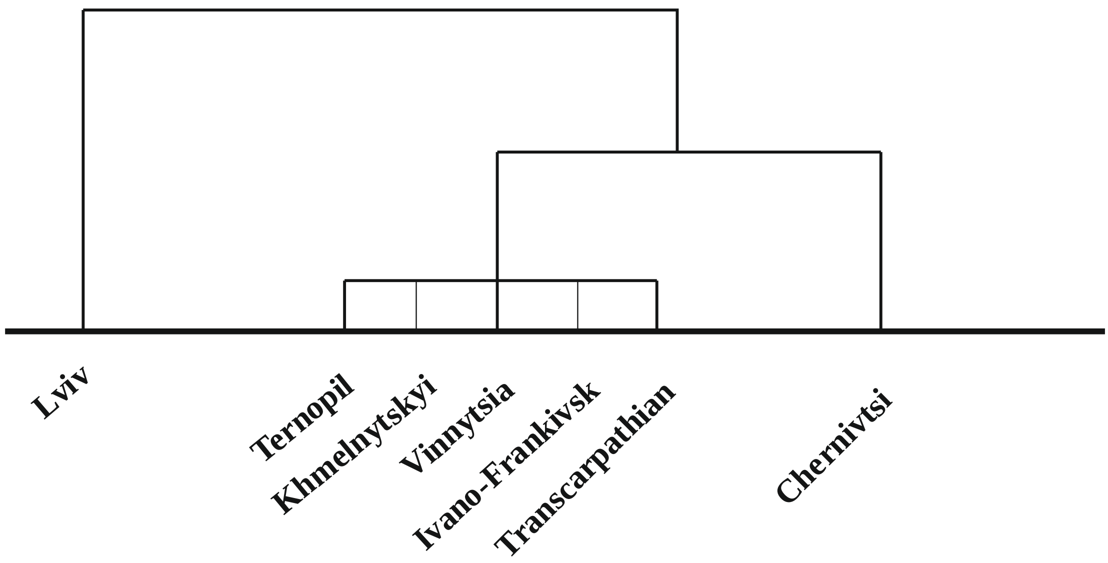

Fig. 1. Clusterization of the areas of the Carpathian-Podillia region according to balance indicators of the social sphere components

Conclusions. The social sphere of Ukraine in general and its major regions are experiencing the period of diversification of its components. With significant potential, the regions of Ukraine do not always use their potential properly.

In the process of consideration of each social sphere component of the Carpathian-Podillia region, we analysed the main groups of criteria. This al-lowed determining the differentiation of levels of social sphere formation of the region in general. On the background of the regional indicator of the social sphere functioning and formation Lviv region is marked by a high level of education, culture, trade and mass catering, as well as communications – these indicators provided the leading positions of the region. For most areas of the region (Vinnytsia, Transcarpathian, Ivano-Frankivsk, Ternopil, Khmelnytskyi) there is a very narrow amplitude of total indicators, which can be a confirmation that in the consolidated form the social sphere does not have a significant difference in these areas. The weakness of the social sphere of Chernivtsi region according to the criteria we have chosen is based on the low positions of the cultural sphere, housing and communal services as well as medical sphere.

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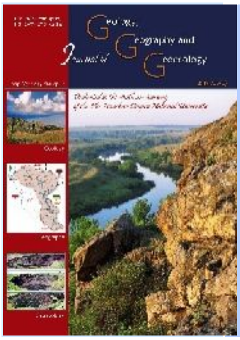

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Geological and structural prerequisites of gas-bearing capacity and gas hydrate formation in the World Ocean (in terms of the Black Sea)

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Abstract. Gas hydrates occurring in the World Ocean are considered as the additional and perspective non-traditional resource of hydrocarbon materials. The proposed classification of deposits as for mining and geological conditions of their occurrence as well as methodological approach to their development and calculation of technological parameters of methane extraction from the World Ocean floor with minimum impact upon the Earth's hydrosphere is of considerable importance in the context of current studies of new and most prospective source of energy in terms of the available experience gap as for the development of gas hydrate deposits. The approach to search for and explore gas hydrate deposits occurring on and under the World Ocean floor has been suggested; the approach is based upon the regularities of gas hydrate distribution in lithological varieties and geological structures. The necessity to take into consideration the pore space enclosing gas hydrate thicknesses to calculate their reserves has been substantiated. The overview of scientific literature sources summarizing the results of marine expeditions as well as the analysis of publications of world scientific community dealing with the studies of gas hydrates has made it possible to determine that gas hydrate deposits are associated to the zones of jointing of continental plates and oceanic troughs. In their turn, those zones, due to different genesis, are made up of the corresponding various products of sedimentary rock accumulations. Detailed analysis of the Black Sea floor structure has been performed. Three geomorphological zones have been singled out; basic types of gas-bearing capacity manifestation and methane liberation from the interior have been represented. Quantitative evaluation of methane content in gas hydrate deposits has been given taking into account the detected ones. Data concerning gas-bearing capacity of the Black Sea floor proved by the map of mud volcanoes location within the areas of gas hydrate sampling have been considered. That was the basis to analyze peculiarities of the formation of bottom-sediment gas hydrates basing upon genetic origin of lithological composition of their enclosing rocks and their structures in terms of the Black Sea floor. Relation between the features of the World Ocean floor structure and the distribution of gas hydrate deposits has been determined. Theoretical approach to search for and explore gas hydrate deposits both in the Black Sea and in the World Ocean has been developed and proposed. Interaction between different zones of the World Ocean floor and types of gas hydrate deposits based upon the compositions of their enclosing rock has been shown. Lithological composition of the rocks enclosing gas hydrates has been analyzed in detail. That will make it possible to determine the type of any specific deposit and elaborate technological scheme to open and develop methane-containing gas hydrate deposits.

Key words: the Black Sea, the World Ocean, gas hydrate, methane, bottom sediments.

Геолого - структурні передумови газоносності та гідратоутворення в Світовому океані (на прикладі Чорного моря)

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Анотація. Родовища газових гідратів є перспективним додатковим джерелом вуглеводневої сировини. На сучасному етапі досліджень цього нового і найбільш перспективного джерела енергетичних ресурсів, має велике значення розробка технологічних параметрів процесу вилучення метану з дна Світового океану з мінімальним впливом на гідросферу Землі. Для досягнення цієї мети, є вельми актуальним встановлення геолого-структурних особливостей залягання цього ресурсу, виявлення закономірностей його поширення в донних відкладеннях та оцінка впливу літологічного складу порід, що вміщують газогідрат на формування його структур. Запропонована класифікація родовищ газових гідратів, що залягають на дні і під дном Світового океану, заснована на закономірностях їх поширення в різних літологічних різновидах і геологічних структурах, надає можливості для їх пошуку і розвідки. Обґрунтовано необхідність врахування оцінки порового простору, що вміщає газогідратні товщі для підрахунку їх запасів. Виконано детальний аналіз будови дна Чорного моря, виділені три геоморфологічних зони і наведені основні види прояви газоносності і виділення метану з надр. На цій основі виконано аналіз особливостей формування газогідратів донних відкладень, на основі генетичного походження літологічного складу порід, що вміщують і їх структур, на прикладі дна Чорного моря. З урахуванням виявлених родовищ газових гідратів, наведена кількісна оцінка вмісту метану в газогідратних відкладеннях.

Ключові слова: Чорне море, Світовий океан, газовий гідрат, метан, донні відкладення.

Introduction. International scientific community considers huge deposits of gas hydrates in the World Ocean as the extra nontraditional source of carbohydrates. Studies of gas hydrates have become more active in recent 50 years. Many of scientists from different countries discuss the issues concerning the availability of gas hydrates and conditions of gas hydrate formations. Over that period, various scientists (Okuda, 1988;Kvenvolden, Robertson, Simons, 1988;Shnyukov, Gozhik, Krayushkin, Klochko, 2007; Makogon, 2010; Chen, Zhou, Su, Liu, Lu, Wang, 2011; Kobolev, 2017 and others) have determined the availability of gas hydrates within the mainland and considerable occurrences of gas hydrate deposits within the shelf and floor of the World Ocean. Such authors as Sloan, 1990;Yamamoto, Terao, Fujii, Ikawa, Seki, Matsuzawa, Kanno, 2014; Zhao, Song, Lim, Lam, 2017) state that gas hydrate reserves ($2 \cdot 1016$ m^3) are comparable to the amount of oxygen in the Earth's atmosphere ($8 \cdot 1017$ m^3). Taking into consideration high specific gas concentration in natural hydrates (up to 160 m / m^3), their relatively shallow occurrence (under seafloor starting from the water depth of 300-500 m) (Byakov, Krugliakova2001), deep-sea hydrates are considered as a real alternative to the traditionally extracted gas. Nowadays, Great Britain, Germany, Canada, China, the USA, Norway, and Japan are involved in the development of gas hydrate extraction technologies.

Japanese and Canadian researchers have made successful attempts of gas hydrate deposit development. In 2012, Japan initiated one of the top-priority national budget-financing programmers in the world aimed at the development of marine gas hydrate deposits of Nankai Trough at the depth of 950 m (Yamamoto, Terao, Fujii, Ikawa, Seki, Matsuzawa, Kanno, 2014). For the first time in the world practice, Japanese gas enterprise has managed to extract gas from the seafloor gas hydrates. The extraction may be called as a well production testing. For instance, Canadian experts have extracted gas from the gas hydrates deposits located within the permafrost zone. Irrespective the facts that gas emission was stable only during six days and the experiments cost CDN 48 mln, scientific community took the news as a real breakthrough in the sphere of "blue fuel" extraction as Arctic area of Canada is characterized by gas hydrate deposits being sufficient to satisfy the needs of Canadian domestic market for some hundred years to come. Topicality of the research is proved by the no availability of both direct and indirect methods to search and explore gas hydrate deposits within the World Ocean floor apart from geophysical one. Geophysical methods are widely applied by modern science to detect such deposits, taking into consideration specific features of their occurrence and expansion. However, to plan any geophysical expeditions, it is important to have previous outline of the zone for searching and exploring; further evaluation of the deposits requires innovative approach considering pore space, facility, and enclosing rock structure. The paper proposes to predict these parameters according to the bottom structure before the beginning of deep drilling operations.

The author deals with the problem not only in terms of the obtaining additional power resource, but also because of the concerns that there may be serious environmental and climatic problems as a result of possible accidental methane release into the atmosphere not only during incorrect development of gas hydrate deposits but also in the context of relatively minor changes in thermodynamic (climatic) conditions being close to the limit of gas hydrate phase stability (Bondarenko, Maksymova, Koval 2013; Maksymova, 2015, 2016, 2018). In other words, as a result of global warming and increase in the World Ocean temperature, deep-sea gas hydrates may begin their uncontrollable decomposition even without human involvement as the shift in phase balance in terms of environmental temperature rise will result in chain reaction of gas liberation. That is true about the Black Sea as well. Currently, there is no scientifically substantiated technology to develop gas hydrate deposits. Rational development of that additional natural energy resource requires the elaboration of a technological scheme taking into consideration the specific geological and morphological structure of each deposit as well as the utmost environmentally friendly technology of gas extraction from gas hydrate deposits. Thus, the main task for today is to formulate a complex approach for that natural resource development. With respect to the available wide-scale worldwide studies in the area, it is obvious that we need detailed analysis of the relations of all the processes within the considered systems from the viewpoint of *geological conditions and regularities*.

Thus, the objective of the paper is to demonstrate the relations between the World Ocean floor peculiarities and the occurrence of gas hydrate deposits, depending upon the enclosing rock composition, for their further possible development.

Analysis of publications. According to the results of scientific papers by E.F. Shnyukov, V.P. Kobolev, A.A. Pasinkov and others (Shnyukov, Kobolev, Pasyinkov 2013; ShnyukovE, Ziborov 2004;Lee, Ryu, Yun, Cho, 2011), generalized complex state-of-the-art study has been carried out to identify and explore gas hydrate deposits by the expeditions from different countries.

Analysis and comparison of numerous maps and aerial survey data of the identified deposits of gas hydrates and zones of global tectonic faults prove the association of the majority of the deposits to the zones of joints of continental plates and abyssal depths [Maksymova, 2013, 2015]. In their turn, due to different genesis, those zones are made up from the corresponding products of sediment accumulation.

The Black Sea floor has been the subject of study since antiquity. According to the conclusions of the international oceanographic expedition by “Aquanaut” research vessel in 1993, one of the hypotheses of the Black Sea origin tells that 7500 years ago there was the planet deepest aquatic lake which level was lower than the modern one by more than 100 m. When the Glacial Era was over, the World Ocean level rose and the Bosporus strait was breached. 100 thousand m^2 of fertile lands being already cultivated were flooded. According to the hypothesis, the Black Sea origin was possibly accompanied by mass mortality of all the lake fresh-water life which decomposition products were represented by methane and hydrogen sulphide. In 1996, theory of the Black Sea flood was also proposed by the geologists William Rayan and Walter Pitman (University of Columbia, the USA); according to their theory there was a massive and catastrophic rise of the Black Sea level (about 5600 B.C.).

Insummer 1890, an expedition headed by I.B. Shpindler equipped 37 deep-water stations; 889 different-depth temperature measurements, 446 specific gravity tests, and 12 draggings were performed. Thus, following facts were proved:

- floorofthecentralBlackSeapartis abasinbeingexclusivelyflat, stretchedapproximatelyfromwesttoeast, withthedepthdownto 2 244 m;
- watertemperaturebeginningfromthedepthof 200 m and down to the floor is uniform being about 9 °;
- salinityatthosedepthsincreasesdowntothefloorveryslowly (upto 22 g/l), atthesametimeitdiffERSsharplyfromthesalinityofthelayerslocatedhigher (about 17 g/l);
- in the summer time, in some places, water temperature down to 50 m is heated up to 25 degrees, then, down to the depth of 100 m, one can observe water layers with the temperature of about 7 degrees;
- at the depth lower than 200 m the water is saturated with hydrogen sulphide, there are no living organisms, and scallops occur in deep deposits that is characteristic only for fresh-water limans.

The deepest water is 2250 m along the axis opposite the Crimean Peninsula. The fact of coincidence in the directions of main axes of basins and axes of mountain folds in the Crimea is of special interest. Orientation of folds in the Crimean Mountains has two systems: the first one is from the north-east to the south-west; the second one is from the south-east to the north-west. The first system being also characteristic for the Balkan folds, is the basic one, it coincides with the direction of the axis of the deepest trough in the Black Sea. The second fold system, corresponding to the folds of the Caucasus Mountains, coincides with the greatest axis of the eastern sea basin.

Thus, the first Black Sea oceanographic survey was crowned with the greatest oceanographic discoveries. Later, there were organized numerous expeditions which confirmed those five key findings.

Retrospectively, gas ingresses were widely highlighted in scientific papers by such geologists as Byakov, R.P. Krugliakova and many other researchers (Byakov, Krugliakova2001; Shnyukov, Ziborov 2004). Great contribution into the study and systematization of the data concerning structure, gas-bearing capacity, and gas hydrates of the Black Sea was made by P.F. Gozhik, V.I. Starostenko, E.F. Shnyukov, V.P. Kobelev, A.E. Lukin (Shnyukov, Gozhik, Krayushkin, Klochko , 2007; Shnyukov, Kobolev, Pasyinkov 2013; Lukin. 2014).

Material and research methods. The paper uses methodically a system analysis of the available gas hydrate deposits, proves the possibility of their extraction, and, considering certain difficulties in carrying out the detailed exploration, develops theoretical approach based upon previous evaluation and mining and geological conditions of the distribution of such deposits. The proposed classification approach to search and explore economically expedient, in terms of methane extraction, zones of the World Ocean floor is of high value at the present stage of studying new additional and the most prospective source of energy resources. For the first time, the interrelation of different zones of the World Ocean floor and the types of gas hydrate deposits has been demonstrated on the basis of their genetic origin and enclosing rock structure.

The basis of theoretical considerations as for the regularities of the formation of gas hydrate deposits is represented by the key concept: relying upon a genetic origin and mining and geological belonging to one or another ocean floor structure, there will be different thermobaric conditions for the be-ginning of gas hydrate formation and deposits accumulation taking into consideration corresponding composition of lithological variations of the enclosing rocks. Floor thickness is represented by the substances ranging from finely dispersed aluminum silicate deposits to quartz fine-grained sands and coarse size breccia of various mineralogical composition of rock-forming thicknesses; it also has indices of heat conductivity, specific heat capacity, porosity, and permeability, being unique for each deposit, that should be also taken into account while selecting the technique for a specific deposit development.

Results and their analysis. There are three basic geomorphological elements within the Black Sea water area: shelf, continental slope, and deep-sea trough. The Black Sea shelf is a flat underwater slope spreading down to 90-150 m. 10-12 thousand years ago it was a plain where rivers flew. When last glaciers melt and retreated to the north, those plains turned to be flooded. Now the shelf covers 24% of the Black Sea floor area. Its width varies. In the north-west, shallow marine shelf stands out to the sea by 200-250 km; at Caucasian and Asia Minor coasts is stands out to the sea only by 6-10 km; somewhere it even ends abruptly at 500 m from the coast. Continental slope is represented by a narrow zone of a steep turn of a seafloor from the outer shelf down to the depth of 1830 m with the steepness of 20-30 degrees. Deep-sea trough of the Black Sea (36% of its water area) is elongated from the west to the east in the form of oval; it bends slightly to the north, its floor is relatively flat, and depths are deeper than 2000 m (Fig.1).

According to the results of the expeditions of the Ministry of Geology of AS of the USSR and the Ministry of Higher Education Institutions of the USSR (1988-1989), deposits of gas hydrate methane and natural gas were found in the Black Sea at the depths of 200-800 m with the thickness of 250-1200 m located lower than the seafloor level with layer thicknesses accounting for dozens of meters.

Fig.1. The Black Seabasin. A lens demonstrates the depths being more than 2000 m. Photo NASA.

Methane resources in gas hydrate deposits opposite the Crimea are estimated to be 20-25 trn m³; the research carried out by the expeditions of the Ministry of Geology of AS of the USSR and the Ministry of Higher Education Institutions of the USSR (1988-1989) shows that according to the seabed drilling and gas hydrate sampling in terms of more than 400 test cores, the amount of methane within the whole Black Sea shelf is not less than 100 trn m³.

First methane bursts took place as a result of the Crimean earthquake, 11 September 1927. A burst of flame being about 500 m high and 1.5-mile-wide was recorded to the east from Sevastopol. Similar bursts were observed from the lighthouse in Yevpatoria; at that, bursts in the form of hot clouds were moving from the north to the south. According to the earthquake description by A.L. Nikonov, within the period from 14 September 1927 to 5 October 1927, columns of white vapor

over the sea surface as well as burning clouds, flames, and even fire columns immersing into the sea with hissing and bursting into flame again were observed near Alushta, Alupka, and Sudak as well as towards Pryvitne settlement
and Feodosia.

From the geographical viewpoint, it is obvious that such gas-bearing capacity is characteristic for different geological structures of the Black Sea floor. If near Yevpatoria it is associated to the continental shelf, then opposite Alushta, Alupka, Sudak it is associated to a much deeper continental slope or even to Sorokin Trough. The latter conclusion is proved by the results of the expedition by the Academic Research Fleet of Ukraine (Shnyukov, Kobolev, Pasyinkov 2013). Abundant gas occurrences are recorded near the coastline of Bulgaria.

Numerous researchers consider the Black Sea as a unique basin in terms of its gas-bearing capacity as it is characterized by rather high seabed gas recovery comparing to other basins of the World Ocean with the discovered hydrocarbon reserves. According to the results of American research expedition by "Knorr" vessel, methane reserves in the Black Sea are 88 bln m^3.

According to the results of expedition by "Professor Vodianytsky" research vessel (2002-2006), it is determined that if methane seeps from the Earth's interior very deep underwater, then gas is formed into a gas hydrate deposit. However, sometimes-unconfined major gas releases break gas hydrate formations. The expedition proved the fact that all the large flames preserved their location and intensity that increased the chances for perspective oil and gas extraction. About 50 mud volcanoes were discovered; however, scientists state that their number is much greater. According to Yevhen Shnyukov, marine geologist, academician of the Academy of Sciences of Ukraine, discharges of some mud volcanoes are similar to some famous Caspian ones where eventually extensive oil fields were established. One more peculiarity of the Black Sea floor is the availability of methane gas hydrate caps; about 20 of them are already found (Fig. 2). Sorokin Trough located 40 km to the south-east from Yalta is one of the most prospective areas of the seabed; the through depth is 2 km.

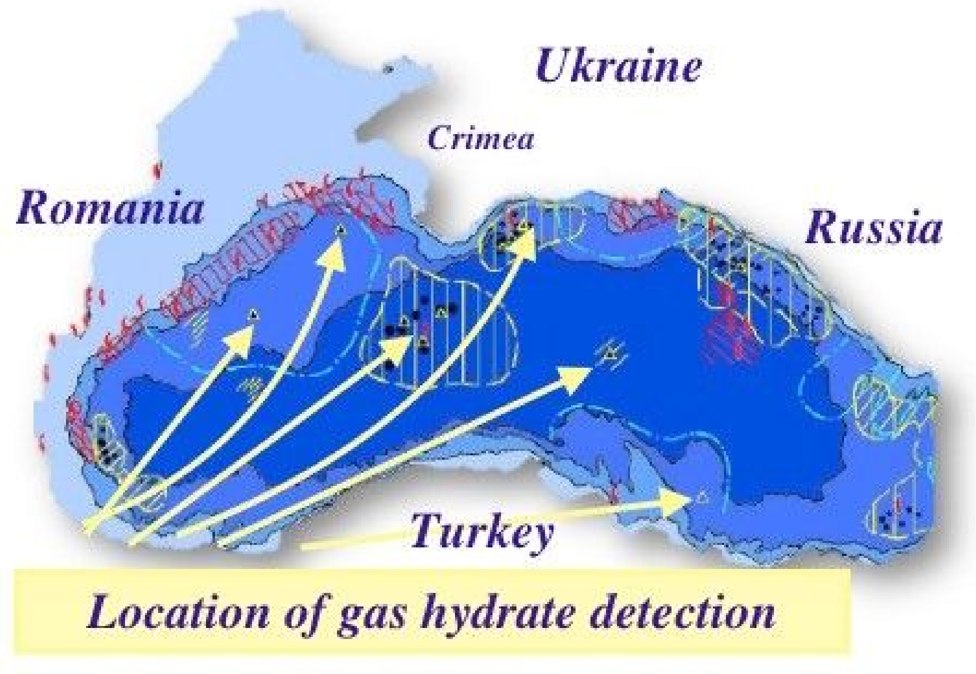

Fig. 2. AreasofgashydratesintheBlackSeadetected during the expedition by "Professor Vodianytsky" research vessel [Shnyukov, Kobolev, Pasyinkov 2013]

Gas hydrate discoveries are located within the large geological structures both in Eastern Black Sea and Western Black Sea troughs. Some scientists (Lozynskyi, Saik, Petlovanyi, Sai, Malanchyk, 2018) consider that only from 1 to 10 % of gases entering the hydrate formation zone are stabilized in gas hydrates.

Perspective areas to search for gas hydrates also include: continental slope (from the depths of 700-800 m to its foot), paleodel deposits of the river fans (Kobolev, Verpakhovskaya, 2014), zones of mud streams and zones of displacements, and zones with the developing diaper structure, first of all, the ones formed by mud volcanoes. Gas-bearing area is also the one represented by the whole territory of central Black Sea fault being the basis for the development of the continental slope as well as the areas of deep and regional faults located deep in the sea, zones of diaper development complicated by mud volcanism, and, possibly, zones of deep-sea subma-rine discharge. Sorokin Trough is also considered to be a perspective area.

Special attention should be paid to paleodel deposits. Considerable occurrences of gas-saturated sludge and gas hydrates can be observed here. Bed deposits contain methane which concentration is by 3-4 times more than the background values. The sampled gases include hydrogen sulphide, methane, and heavy hydrocarbons.

According to the results of the Black Seas seismic and geoacoustic surveying, numerous anomalies demonstrating the availability of gas hydrates were singled out. Such areas are known within the western part of the trough, barrier anticlinal zone, Palas Rise, Sorokin Trough, Anapa Rise, and at the foot of the Caucasian continental slope. More than a dozen of gas hydrate discoveries in the surface layer of bed deposits were recorded in the Black Sea; bed deposit interval was 0.6-2.85 m (within the Crimean continental slope, Palas Rise etc.). Gas hydrate methane deposits with the thickness of 400-800 m under the seabed were found within some areas of the Black Sea at the depth of 300-1000 m.

Geological and geophysical data and literature sources by the scientists of the NAS IGS of Ukraine who studied north-west and Kerch-Feodosia areas of the Black Sea basin shelves were used to develop a map of the perspective structures of gas hydrates and hydrocarbon deposits.

Thestartofhydrocarbonexplorationinthatregiondatesbacktothe 1950s. In 1976, the research carried out by seismic survey robots of the Black Sea geophysical expedition by "Krymmorheologiia" association (Gruzer, F.L. and others) proved the availability of Kerch-Taman periclinal transverse trough; in addition, Southern-Kerch and Subotin structures were determined in association with "Yuzhmorheo" CGE RMA. In 1978-1982, comprehensive maps of different levels of Meso-Cenozoic Subotin, Sokolov, Hlyboka etc. structures were developed basing upon the detailed seismic surveying carried out by "Soiuzmorheo".

According to the detailed seismic surveying with the application of modern techniques, Subotin structure is among the largest ones in terms of local structures determined within Kerch shelf. In 2005, a parametric well No. 403-Subotin was drilled within the vault part of Subotin structure; the purpose was to specify lithological and stratigraphic differentiation of the opened section as well as its facies and formation characteristics, to study conditions of the occurrence of perspective Cretaceous-Neogene complexes, to obtain geological and geophysical parameters for lithological and stratigraphic association, to understand the levels, data on physical properties of rocks as well as physical and chemical characteristics of the formation fluids required to inter-pret seismic exploration commercial and geophysical studies, to define perspectives of oil-and-gas bearing capacity of the opened section, and to refine the evaluation of the unexplored hydrocarbon resources. Target well depth is 4300 m; true well depth is 4300; target level is Paleocene-Upper Cretaceous; true achieved level is Lower Eocene.

Geological surveying vessel "Iskatel" has determined 35 bln m^3 of gas within the northern-eastern Black Sea shelf in Odesa region.

Government program – 2020 stipulates complete provision of Ukraine with its own energy carriers. The fact that Ukraine has renewed oil-and-gas explorations within the Black Sea shelf demonstrates the considerable progress in Ukrainian geological prospecting. According to the estimations by geological explorations, gas reserves within the shelf are not less than 40 bln m^3 within the area of 7 thousand m^2 of the northern-western Black Sea shelf. Ukraine has sufficient amount of resources to satisfy own gas needs; moreover, Ukraine has the possibilities to extract gas on its own. The papers by A.Ye. Lukinov establish genetic relations between the tectonic and geodynamic peculiarities and conditions of generation, migration, and accumulation of the Black Sea region hydrocarbons and Caspian mega basin, which is considered to be unique in terms of, oil-and-gas bearing capacity. The scientist points out that we have all reasons to state that in terms of the corresponding measures of the Black Sea basin exploration, similar to the Caspian one, the number of oil-and-gas deposits in the Black Sea will be not less than the ones of the Caspian area (Lukin, 2014).

Thus, taking into consideration rather abundant methane content of the Black Sea trough, depths, and their temperature mode, it is obvious that there are all the required prerequisites of methane generation. Basic mass of gas hydrates confirmed by sampling is accounted for Ukraine and Romania; less gas hydrate amounts are accounted for Turkey, Bulgaria, and Russia.

Structure of the Black Sea floor and bed deposits enclosing gas hydrate formations

The author has carried out a detailed analysis of the floor structure from the viewpoint of the sedimentary cover enclosing gas hydrates of rocks; the analysis is of high importance to have good understanding of the conditions for the formation of gas hydrate deposits as well as peculiarities of

thermal and physical properties of their enclosing rocks to develop further schemes of extracting that valuable
energy resource.

Beginning from the depth of 25-50 m, bed deposits of the Black Sea are represented by gravel and sand. The Black Sea shelf starts from the coast and goes down to the depth of 100-140 m. Generally, at the levels higher than 2000 m depths, within the lim-its of firths, sedimentations of a steep continental slope are stipulated by river discharge; they are rep-resented by sand, pebbles, and mud bank with shells. Remains of mussels and horse mussels can be found within the shelf. They form so-called phaseoline ooze. Central part of the Black Sea floor, deeper than 200 m, is represented by abyssal plain represented by bluish-grey terrigenous mud; occasionally it is covered with white encrustation of amorphous carbonate limestone. Sedimentation mass occurs on a basalt bed covering the Earth's mantle.

Huge quantities of benthos, plankton, zooplankton, and other biomass defined and evaluated by the scientists of the Institute of the Biology of Southern Seas of the NAS of Ukraine may be additional sources of organics along with endogenous methane. Not only benthos but also some species of plankton was found by the scientists within the hydro sulfuric zone of the Black Sea as well as at the depths being more than 1500 m near the seafloor. That is an interesting fact confirming genetic connection of the Black Sea with fresh-water complexes. Bathyal zone of the Black Sea bottom, covering both shelf and continental slope depths, i.e. from 200 m down to 3000 m, is colonized: total amount of zooplankton at the depths of 0-50 m is within the range of 347-7185 sp. / m^3; biomass – 29.19-330.98 mg / m^3; average values of total number of planktonic organism biomass in bottom sediments in terms of two depth ranges being 1250-1850 m and 2060-2110 vary from 1 867 to 18844 sp. / 0.1 $m^2$and from 98.91 to 1195.97 mg / 0.1 m^2 respectively. Not less than 100 mln tons of organics per year merged into the lower sea layer being taken by sulfate-reducing bacteria generating hydrogen sulphide. Sediment accumulation rate in the Black Sea in not less than 1 m / th years, 100 m per 100 th years, and 1 km per one mln years.

Thickness of bottom sediments accumulated in the Black Sea basin (within the abyssal plain) is 4-8 times more than the depth of the Black Sea water column; thus, the thickness is from 8 to 16 km. That is the thickest layer of the World Ocean bottom deposit. Analysis of core samples from the depths of several thousand meters under the seabed from various regions of the Pacific and Atlantic Oceans as well as the Black Sea demonstrates that archaea prevail having adapted to live in such a complex environment (Chen, Zhou, Su, Liu, Lu, Wang, 2011).

Archaea live on ooze, mud, and remains, petrified and processed by other organisms. As a result of their activity, archaea generate methane.
According to the literature data and the studies by the Institute of Geological Sciences of the NAS of Ukraine, S.I. Subotin Institute of Geophysics of the NAS of Ukraine, Marine Hydrophysical Institute, and the Department of Marine Geology and Sedimental Ore-Formation of the National Museum of Natural History of the NAS of Ukraine, the generalized crosscut of deep water bottom sediments of the Black Sea is as follows:

1. Modern sediment layer is the surface layer with the thickness up to 1 m (maximum thickness is 1.09 m) consisting of the alternating thinnest interlayers (0.5-3 mm) of oozy substance with coccolith inclusions.

2. Ancient Black Sea deposits are characterized by the increased amount of organic substance. The complex consists of three layers:

Upper intermediate layer enriched with organic substance represented by high-plastic grey and reddish-brown (within the areas of decay ooze) micro-layered oozes. That layer thickness is about 0.20 m (maximum thickness is 0.6. m). Upper boundary of the complex is clear due to almost constant availability of turbidities-argillaceous interlayers within its roof.

Middle layer is represented by sapropel being homogeneous, dense, and olive green to black in its color. Its average density is 0.40-0.50 m at maximum value of 0.80 m.

Lower level is represented by pelitic dark-greyish ooze with the characteristic increased content of organic substance. In addition, they are separated by the interlayers of turbidities.

3. Novoeuxinian deposits are not opened to their full capacity (down to 3 m from their roof). The opened cut of Novoeuxinian deposits is represented by three benches (Bondarenko, Vytiaz, Zotsenko, 2015):

Upper bench is made up by light grey oozes with the thickness up to 0.40 m. At the top, within the boundary with sapropel level, turbidities interlayer is often observed. There is the same layer (up to 0.1-0.11 m) within the lower boundary of the oozes. Lower, there are the benches of terrigenous pelitic muds being plastic, bluish-grey with hydrotroilite interlayers within their lower share. Occasionally, there can be observed a turbidities level (up to 0.12 m) within the thickness of the bench; the basis of that level is represented by the interlayers of fine-grained sand, changing upwards into muddy sediments, and by inclusions of dense yellowish-brown clay.

The lowest bench, among the opened Novoeuxinian ones, is represented by black hydrotroilite oozes, with occasional minor interlayers of terrigenous blue-grey ooze.

Threegenetictypesofsedimentsaresingledou-tinadeep waterpartoftheBlackSea: terrigenous, biogenous, andterrigenous-biogenous. In their texture, sediments are layered, sometimes cryptolayered, with flowing or soft consistency. Biogenous oozes are represented by coccolith, sapro-pel, sapropel-like, and sapropel-coccolith varieties. In terms of physical and mechanical properties, oozes are represented by the types ranging from liquid to high-plastic ones.

Such a detailed analysis of lithological composition carried out by the scientists of the NAS of Ukraine is of high importance; thus, the author of the paper takes it as the basis for the developed methodology to calculate the dissociation rate of various-genesis gas hydrate thicknesses. Those lithological varieties have individual indices of thermal capacity, thermal conductivity, porosity etc. being essential while developing such deposits in future.

Having studied and analyzed numerous national and foreign literature sources dealing with nat-ural gas hydrates, the author of the paper interlinks conditions of their formation in the World Ocean in general and in the Black Sea in particular and bottom sediments being their enclosing rocks. Apart from high pressure and low temperature, such parameters as gas saturation, porosity, and thermal conductivity of a certain lithological difference are of considerable importance.

The author is stick to the hypothesis of hydrate formation from the Earth’s crust interior (Maksymova, 2013). Its essence is in the fact that methane outgoes from the Earth’s interior through faults in the oceanic crust from deep depths, about several dozens of kilometers. Gas flows go through geological sedimentary layers of sea and ocean floors. Certain conditions (increased pressure -from 11 MPa to 15 MPa and low temperatures - from 5 ° C to 14 ° C), in terms of the available water, effect natural gases; finally, gas hydrates are formed (Fig. 3).

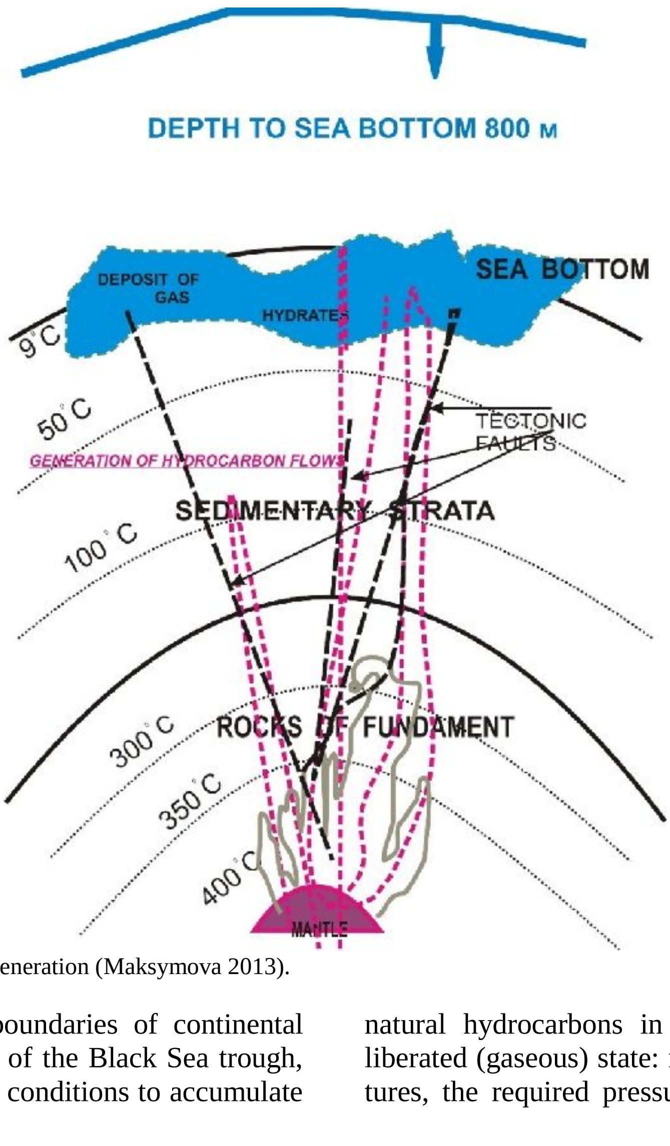

Fig. 3. Scheme of gas hydrates generation (Maksymova 2013).

Thus, within the boundaries of continental slope and deep water bed of the Black Sea trough, there are all the necessary conditions to accumulate natural hydrocarbons in solid (gas hydrate) and liberated (gaseous) state: rather low water temperatures, the required pressure, alternation of porous and argillaceous sediments in the cut, wide-scale gas-bearing capacity of the water basin. Geological zones of gas hydrate development are often connected with the development of argillaceous diapers complicated by mud volcanoes. Fragments and separate inclusions of gas hydrates are often found in the outbursts of mud volcanoes. Thickness of gas hydrate deposits may reach up to 400 – 500 m; in some cases, the thickness may be even 1000 m. As a rule, under-hydrate gas is accumulated under the gas hy-drate deposits. The Black Sea gas hydrates are most often represented by irregular fine inclusions within the semi-liquid oozes, snow-like flakes, or cakes located both on and in the cavities of oozes of various lithological composition. Gas hydrates may develop both in quaternary and Neogene deposits. Deposits containing gas hydrates forms impermeable cover for gases; under-hydrate gas deposits are accumulated under that cover.

It is quite possible that the whole system is in dynamic balance; however, the system, experiencing certain unloading through the funnels of volcanoes and by means of gushers, is refilled at the expense of gas deposits from the deeper levels in the interior.

Scientists of different periods of time developed various classifications of gas hydrate deposits according to the conditions of accumulation and availability: in terms of cryohydrate features, depending upon the phase state of rock fluids (Istomin, Yakushev, 1992), in terms of geological and physical peculiarities (Moridis, 2003), and as for thermobaric condition of the occurrence (Makogon, 1997).

In the author's opinion, a classification is required to achieve final practical objective. The objective is the development of that unusual new energy resource with maximally possible expediency and minimum impact upon the World Ocean environment. That is why classification features are taken in a complex way, i.e. in terms of the origin of the deposits, conditions of their future development, peculiarities of porous medium, and structural features. Basing upon the detailed analysis of the origin of gas hydrate deposits as well as upon structure and lithological composition of gas hydrate enclosing rocks, their corresponding classification in terms of genetic type has been developed. The author has developed classification according to the substance composition of the enclosing rocks and their geological and structural features (Maksymova, 2013):

Type one. Gas hydrate deposits representing continuous deposits on the sea and ocean floors, within shelves and troughs as well as within large tectonic disturbances: along faults, rises, displacements, and inside grabens. Those amorphous deposits of gas hydrates are in the form of pure ice occurring as independent layer of considerable thickness (from 2-3 m up to 150-200 m). While selecting the development technique for those deposits, it is required to take into consideration their high and intense specific gas recovery factor reaching 80-90 %.

Type two. Gas hydrate deposits in the form of continuous thicknesses with practically homogeneous, fine-grained structures of gas hydrate masses occurring in shelves and troughs of seas and oceans, mostly in sands, abraded coarse-grained crushed cataclasites, within the boundary and under the seabed; they may also occur in the continents in the permafrost zones within the boundaries of buried faults. Those are uncemented or weakly cemented terrigenous deposits with super capillary porous channels of 0.5-2.0 mm in diameter. While estimating the reserves and selecting the development technique for the deposits of type two, it should be taken into account that specific gas recovery factor will be up to 60 %, and porosity value should be taken within the range of 60-80 %.

Type three. Gas hydrate deposits associated to sabulous, argillaceous, and mud deposits which capillary pores are 0.0002-0.5 mm being saturated with gas hydrate. Porosity values are within the range of 40-60 %. They may form layered and blanket deposits occurring at different slope angles of anticlinal or synclinal folds, under the sea and ocean floors. In terms of such deposits, specific gas recovery factor is not more than 50 %, the process of development will be accompanied by considerable losses at the expense of the available turbulent conditions.

Type four. Gas hydrate deposits within the fragments of rock breccia of various types. Such a deposit type is formed under different geodynamic conditions; it is characterized by rather diverse structure of the enclosing thickness and formed at the points of rock mass displacements under the floors of seas and oceans as well as within the permafrost areas. Values of porosity and permeability will fluctuate within a wide range depending upon the lithological differences of the enclosing thickness and tectonic fragmentation.

Type five. Gas hydrate deposits in the form of vein deposits formed within large masses of magmatic rocks, along faults; correspondingly, gas hydrates occur in the form of large veins. They are of mixed structure – from visible coarse-grained breccia to amorphous ones occurring under the sea and ocean floors; they may be also available within the permafrost zones. In other words, in terms of large veins, cavities, or caves, gas hydrate will not occur in the form of type one, in the form of pure ice with the highest values of permeability and specific gas recovery factor. In terms of non-vein areas, so-called border zones of tectonic faults, gas hydrate deposits will be characterized by filtration indices of either type three or type four of the classification.

The classification means further supplementing and correcting taking into consideration the results of geological explorations of gas hydrate deposits according to the current expeditions carried out in different countries.

Conclusions.

1. Association of the deposits of oil, gas, gas-condensate, and gas hydrates of the sedimentary cover to the tectonic structure of the Earth's crust as the additional sign to discover gas hydrate deposits has been proved.

2. Classification of natural deposits of gas hydrates according to the types depending upon their belonging to various tectonic structures, occurrence conditions, and material composition of their enclosing rock has been developed. Distribution of gas hydrate deposits according to their genetic origin makes it possible to be more specified in the selection of rational technological schemes of their development.

3. Methodological approach to evaluate gas hydrate deposits has been elaborated to select the appropriate technological schemes of the processes to extract methane from the World Ocean floor with minimum impact upon the Earth's hydrosphere.

4. It is proposed to develop methods and technologies for gas extraction from natural gas hydrate deposits on the basis of the corresponding deposit types.

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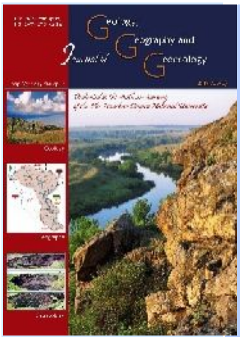

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Mineralogical characterization of limonitic iron ore from the Rouina mine, Ain Defla (Algeria).

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Abstract. The Rouina mine is one of the oldest operated mines of iron ore in Algeria, its product is used like an adjuvant in the cement industry because the extracted raw material is considered as a low-grade ore. The present paper investigates on the one hand its mineralogical composition with the aim of understanding the morphology, texture, phase identification and iron properties**;** and on the other hand studying the influence of washing on its quality. For characterization, X-Ray Diffractions (XRD) of collected samples, analysis of thin sections with scanning electron microscope (SEM), and a sieve analysis followed by washing of each size fraction using a sieve mesh 0.074 µm were adopted. The obtained results revealed that the raw material of the Rouina mine is clayey low-grade iron ore and it is possible to obtain a pre-concentrate through the washing method. This article suggests in addition conducting deep studies of Rouina iron ore with physico-chemical characterization in order to confirm the prior results (mineralogical characterization) and then to permit a suitable enrichment method to be applied with the aim of obtaining a high-grade iron ore acceptable for the metallurgical industry.

Keywords: the Rouinamine, iron ore, cement, mineralogical, washing, enrichment.

Мінералогічна характеристика лімонітової залізної руди з шахти Руйна, Айн-Дефла (Алжир).

Алі Месса, Абделазіз Ідре, Айса Бенсельхуб

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Анотація.Шахта Роуїна - одна з найстаріших експлуатованих шахт залізної руди в Алжирі, її продукція використовується як допоміжний компонент в цементній промисловості, оскільки вилучена сировина вважається низькосортною рудою. Дана робота досліджує з обного боку мінералогічний склад сировини з метою розуміння морфології, текстури, фазової ідентифікації та властивостей заліза; а з іншого боку - вивчення впливу промивання руди на її якість. Для характеристики рентгенівських дифракцій (XRD) зібраних зразків, аналізувалися тонкізрізи із скануванням електронним мікроскопом (SEM) та проводився ситовий аналіз з подальшою промиванням кожної розмірної фракції з використаннямсита 0,074 мкм. Отримані результати показали, що сировина шахти Роуїна - глиниста низькосортна залізна руда, і вона придатна для отримання попереднього концентрату методом промивання. Це дослідження передбачає, крім того, проведення глибоких досліджень залізної руди Руїни з фізико-хімічною характеристикою для підтвердження попередніх результатів (мінералогічна характеристика) і дозволяє у подальшому застосувати відповідний метод збагачення з метою отримання повноцінної залізної руди, придатної для металургійної промисловості.

Ключові слова: *шахта Руїна, залізна руда, цемент, мінералогічний, промивання, збагачення.*

Introduction. Problem setting. Iron is the main component of the steel industry, that why it plays a significant role in the evolution of the global economy (R.J. Holmes, L. Lu 2015). The growing demand for iron as a raw material coupled with the deterioration and exhaustion of high-grade iron ore deposits is a serious problem for the steel industry on a global scale (Matis, K. A et al 1993). The enrich-ment of low-grade iron ores, that are used like an adjuvant in the cement and ceramic industries, repre-sents an alternative solution for the future which would ensure the continued availability of raw materials (Li Ch et al 2010, Da Silva F.L et al 2014, Liu, S et al 2014, Osinubi, K.J et al 2015, Singh, S et al 2015).

Kesearch on valorisation is commonly re-lated to the physicochemical and mineralogical composition of minerals and their liberation size (Rath, S. S et al 2016) where low-grade iron ores are capable of being enriched by primary mechani-cal preparation (crushing and grinding), magnetic, gravimetric separation and the flotation method, (A. Jankovic 2015, D. Xiong, L et al 2015)

Several deposits are located in the North-West of Algeria at Rouina, Zaccar and Beni Saf (Popov 1976). These deposits were identified as metasomatic carbonate replacement deposits that were formed through the process of epigenetic re-placement of limestone by siderite followed by supergene enrichment by hematite. (Chaa, H., & Boutaleb, A. 2016)

The Rouina mine is one of the oldest oper-ated mines in Algeria and its production is designed for the cement industry because it is considered as low-grade iron ore that contains a high percentage of clay materials .However, most previous studies are not detailed enough to assess the possibility of its enrichment for obtaining a high tenor concen-trate for use in other field industries such as the steel industry and, the pigments manufacture.

Because of the lack of real mineralogical ore characterisation , this paper presents the X-Ray Diffraction (XRD) and Scanning Electron Micro-scope (SEM) results. The (XRD) and (SEM) were used on collected samples and thin sections; the quality and the quantity of minerals contained in Rouina deposit were investigated .Then, a washing test of different particle sizes was carried out, which permitted us to estimate the liberation where clay materials were removed from useful minerals.

Study area description. *Geographic situa-tion.*TheRouina iron ore deposit is situated in the town of Rouina, the state of Ain Defla in the north west of Algeria. The national road N° 04 linking Algiers with Oran passes 3 kilometres from the deposit; the geographic situation is illustrated in Figure 1.

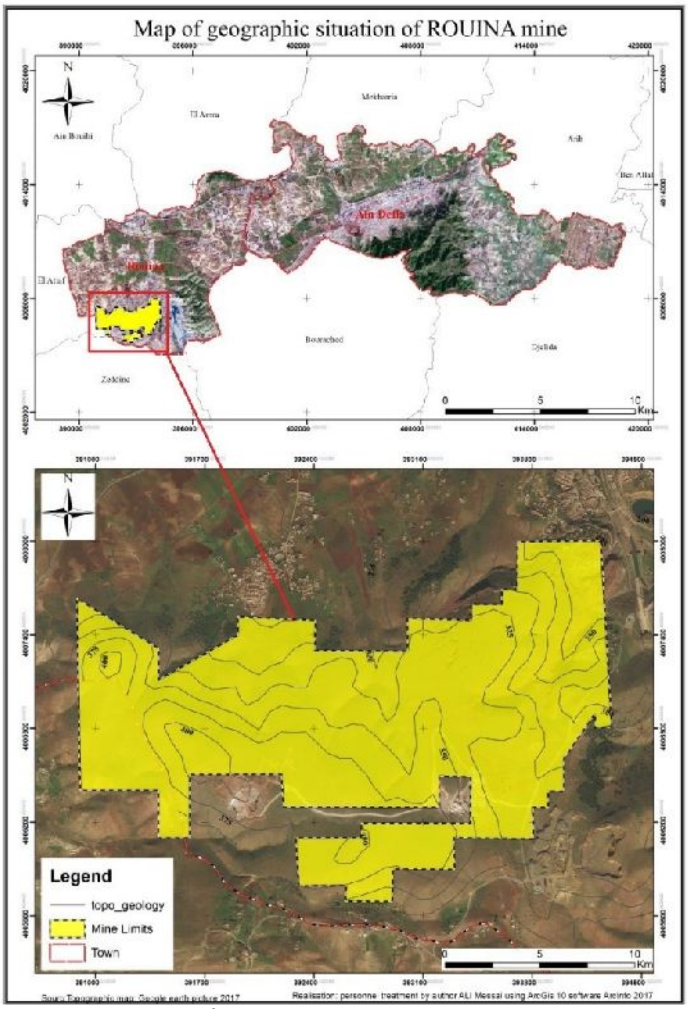


Fig.1. Geographic situation of Rouina mine –Ain Defla

Local geology. The Rouina iron deposit is a part of the Rouina massif. This massif originated after the Alpine orogeny at the borders of the mega geosyncline, in the form of a directional anticlinal 30°- 40° NE emerging in the middle of the alluvial deposits of the Chlef Valley. Figure 2 illustrates the re-gional geology and the location of the Rouina deposit.

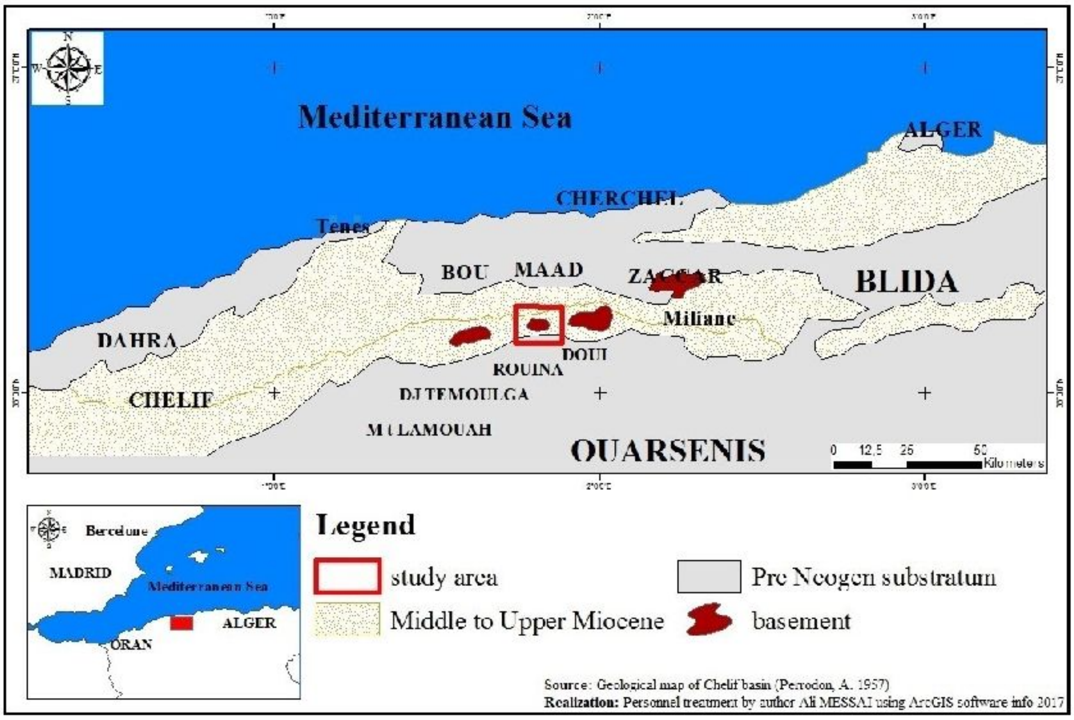


Fig.2. Simplified geological map of the Chelif basin (Personal treatment by author Ali MESSAI) (Perrodon, A. 1957)

The flanks of this anticline are composed of secondary carbonate soils with dips growing from the heart to the exterior including Paleozoic formations.

For the Rouina massif, it consists mainly of:

- The schist sandstone and conglomerates series of the Paleozoic;
- The carbonate benches (limestone and shale) of the Jurassic, which presents the majority of outcrops in Rouina;
- The marls outcrop of Lower Cretaceous;
- The basic conglomerate that marks the contact between the base and the cover.

We also note the absence of the Triassic and Tertiary and the Quaternary soils. Thus, the iron mineralization of Rouina appeared in the Triassic and Jurassic periods (Middle Lias) and it was formed before at least 245 million years ago. (RAACH Khadidja. 2010)

There are two major litho-stratigraphic formations; Jurassic and Cretaceous.

Jurassic. The Jurassic represents the majority of outcrops in Rouina. As everywhere in the western of Algeria, the Jurassic constitute of massive carbonate banks.

a- Lias : It is discordant on the Paleozoic basement in favour of a thin layer (few meters), including pale grey and purplish shale elements, it testifies the passage of Paleozoic schist to Jurassic limestone; its age is not precise. The basic conglomerate is followed by a rather thick layer of greyish limestone attributed to the Lower Lias.

Reddish limestone in the higher levels shows microscopically fine calcite ranges including digenetic quartz grains, coarser limestone, sometimes pigmented iron, crossed by fractures filled with oxides and hydroxides of iron. This formation is of Middle Lias age.

b- Dogger: A compact formation of bluish-grey massive limestone rich in flint nodules surmounts the Middle Lias; its strength is about 50 m. The microscopic study done by (Kireche, O. 1993) reveals the presence of jaw debris and micro-filaments, found in the Dogger faces of the Tellian regions, which allowed it to be assigned a Dogger age.

c- Marl: A limestone and marl-limestone series in small banks, located above the Dogger series

d- *Cretaceous.* On the west of the Rouina valley, a narrow outcrop of green gray marl above the Jurassic limestone is recognized as Upper Cretaceous.

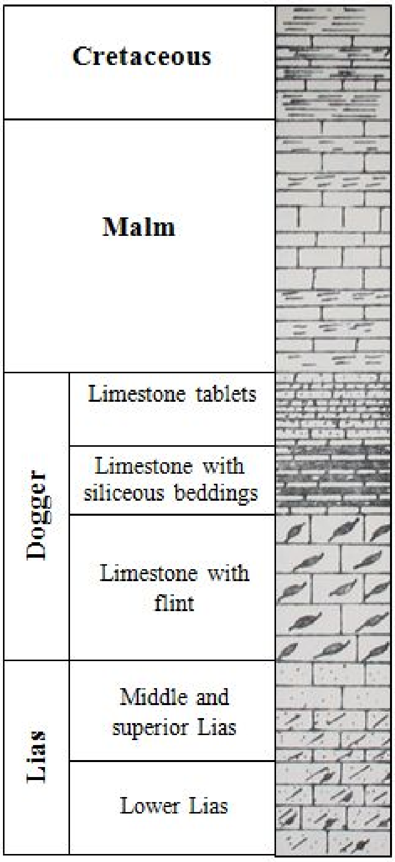


Fig.3. Stratigraphic column of Rouina (personal treatment by author Ali MESSAI) (Kireche, O. 1977)

Methods and Materials. The first task mineral characterisation

Sampling. The sample weighing 120 kg with the maximum diameter of lumps about 120 mm was selected from the open pit mining. The protocol of sampling was realized to prepare samples intended for definition of physico-chemical and mineralogical characteristics.

Figure 4 presents a geological map of the Rouina massif treated using the Geographical Information System (ArcGIS 10) 2017 software to illustrate the geology of the "BUTTE" deposit where the samples were collected.

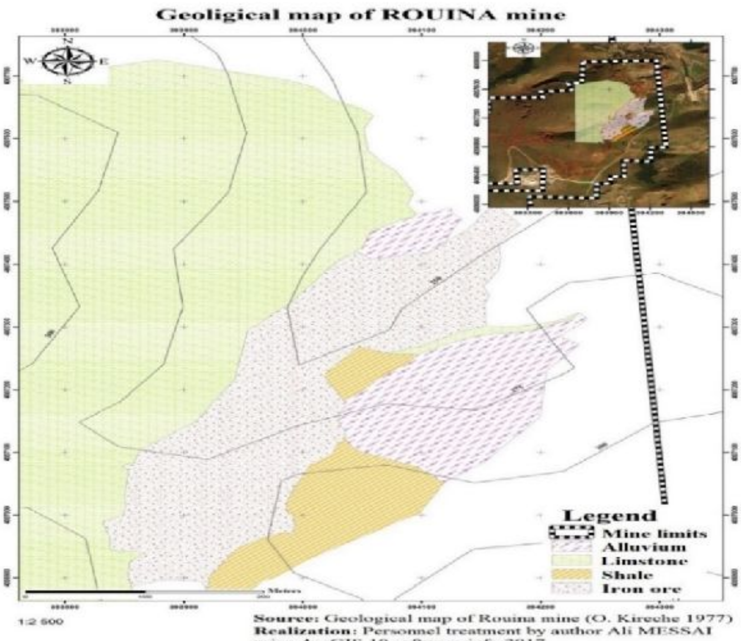


Fig.4: Geological map of Rouina massif (personal treatment by author Ali MESSAI) (Kirreche, O. 1977)

Mineralogical characterization. This task permits us to identify and quantify minerals contained in the material studied.

In this step, two different techniques are applied. X-Ray Diffractions (XRD) using PAN analytical Diffractometer : XPERT-PRO, equipped with Copper Anticathode Ceramic X-ray Tube, The current and voltage were 40 mA, 45 Kv respectively and on the other hand by observation of thin section using Scanning Electron Microscope (SEM) type SEM7001F.

Size analysis. This was conducted on quantity of 600 grams of dried raw material primarily crushed to 5 mm, a shaking machine, type RETSCH and sieves series assembly of: 2, 1, 0.5, 0.25, 0.125 and 0.063 mm were used. each sample is sieved for 30 minutes with magnitude of 60 mm/g. The refusal mass of each sieve is weighed using a scale with an accuracy of 0.01g.

Washing. The refusing masses prepared with size analysis washed using a sieve with an aperture of 0.074 mm (Figure 5), all of washed fractions were viewed under a petrographic microscope and the liberation sizes chosen are analysed by XRD (X-Ray Diffraction).

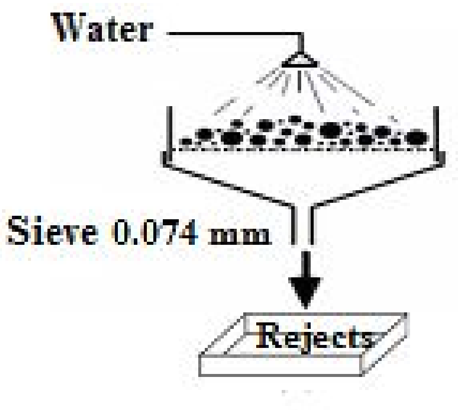


Fig.5. Washing of different fractions

Results and Discussion

X-Ray diffraction

Figure 6 represents the diffractogram obtained by the XRD, and demonstrates the presence of iron oxides (hematite Fe_2O_3 and goethite $FeO(OH)$) and quartz (SiO_2) as major mineral phases. It also proves the presence of illite (clay mineral) K ($Al_4Si_2O_9$ $(OH)_3$) besides calcite $CaCO_3$

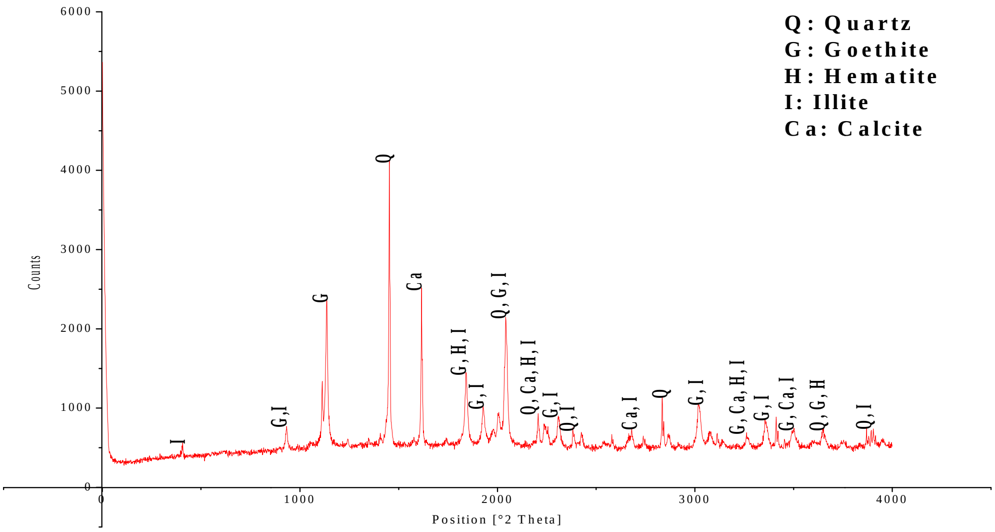


Fig.6. Diffractogram of raw material

Scanning Electron Microscope (SEM).

Observation of thin sections. Three series of observations were performed on the thin sections and the results are illustrated in Figures 7 (a, b and c). We noticed the presence of quartz (greyish black) like a dominant element related to iron oxides, that has a white colour (Figure 7.a). , we also noted the presence of quartz bathed in a mass of goethite pre-sents in hilly forms (Figure b) to erased structure of finely fibrous aggregates (Figure c).

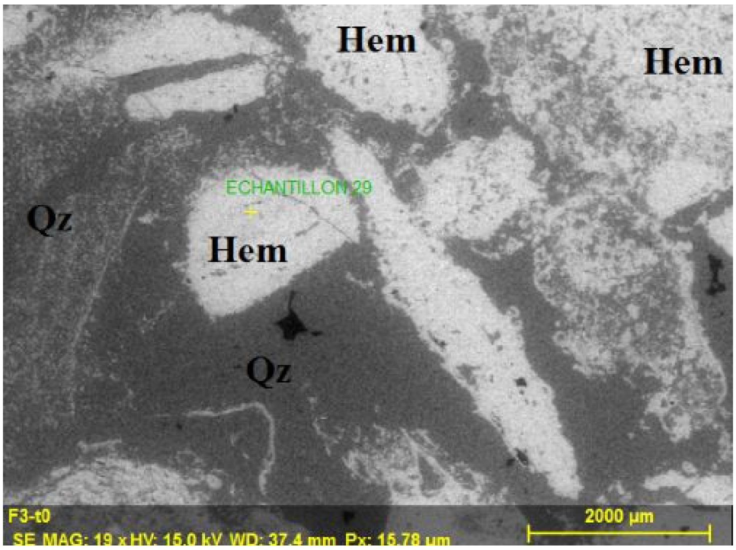


Fig.7a. Thin section 1 under SEM; Quartz associated with hematite (Hem: hematite, Qz: quartz) Whitney, D. L., & Evans, B. W. (2010).

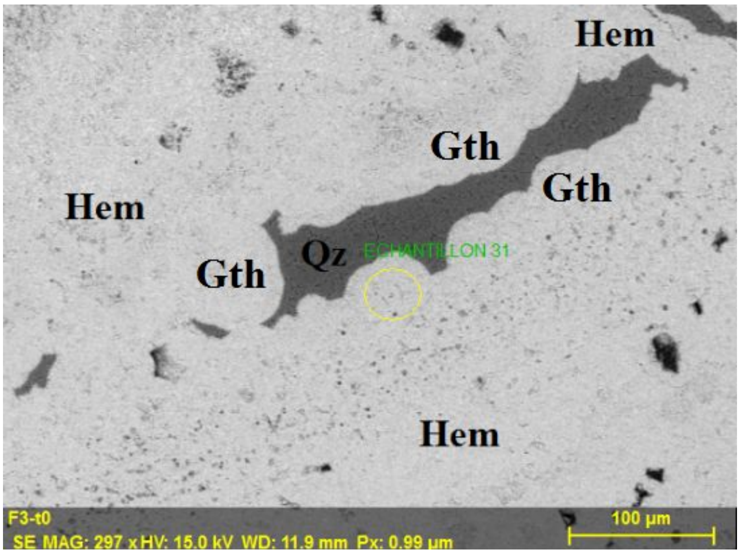


Fig.7b. Thin section 2 under SEM; quartz bathed in a hematite cluster and goethite, (Hem: hematite, Gth: Goethite and Qz: quartz) Whitney, D. L., & Evans, B. W. (2010).

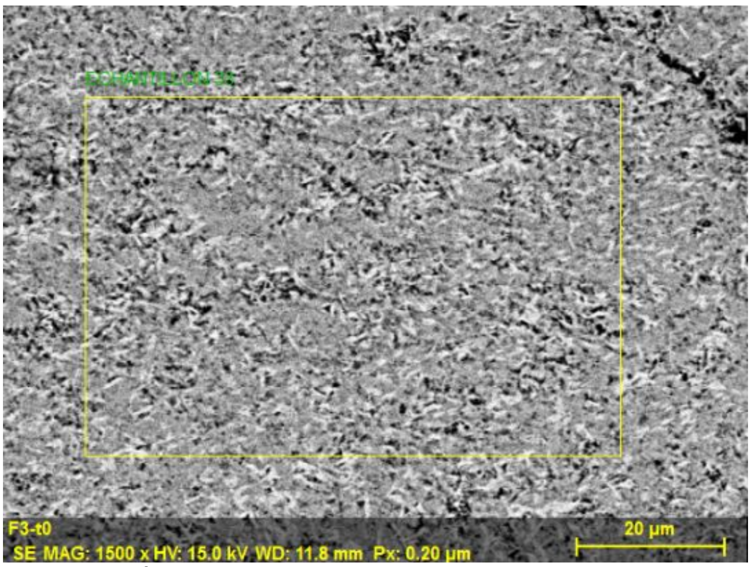
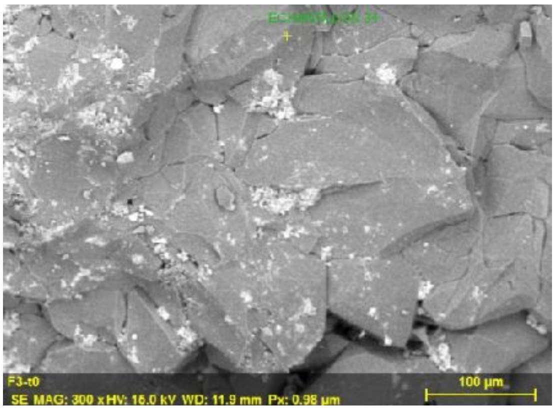


Fig.7c. Thin section 3 under SEM; Mass of iron oxides and hydroxides interacting with quartz

Particles Observation of particles. In order to confirm the results obtained previously of raw material samples and the thin sections, some particles were chosen in order to observe them with the SEM. The results are illustrated in Figure 8 (A_1, B_1, A_2, B_2, A_3, B_3, A_4, B_4, A_5, B_5), where hematite and goethite (white colour), quartz (black greyish colour), traces of clays and besides calcite (black colour) are observed, which is in good agreement with DRX results and results of analysis of this section.

A_1)



B_1)

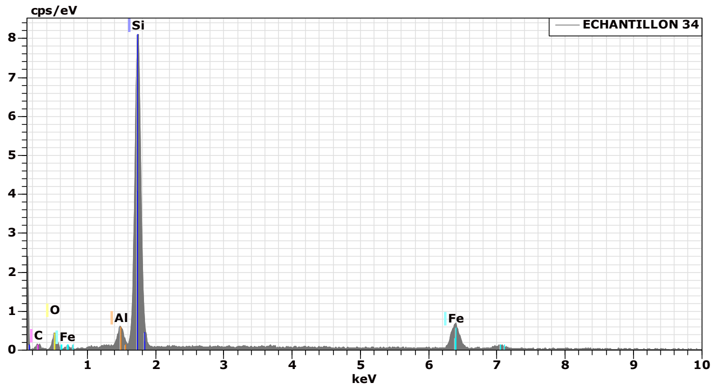
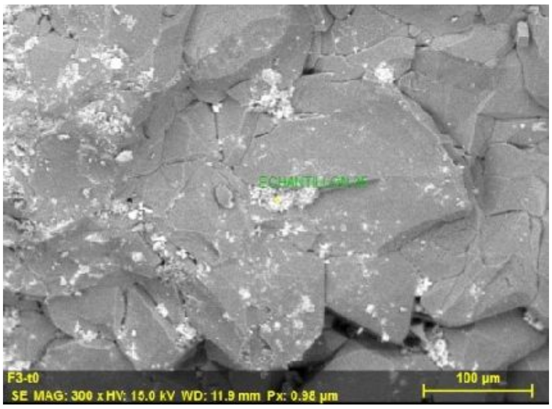


Fig.A_1. 1st particle under SEM; scanned point shows quartz as a dominant mineral

A_2)



B_2)

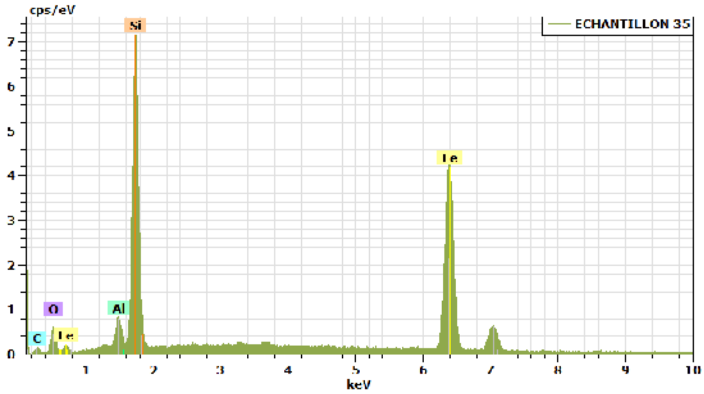
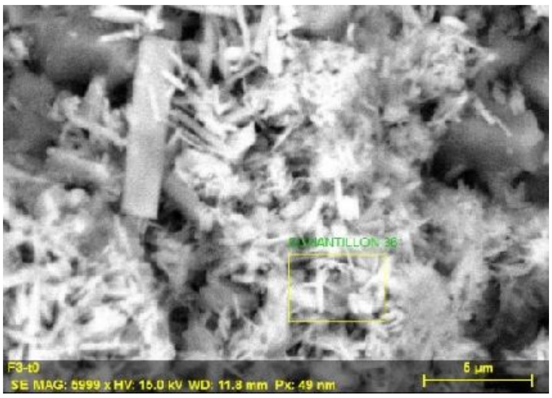


Fig.A_2. 1st particle under SEM; scanned point shows trace of hematite contained on quartz

A_3)



B_3)

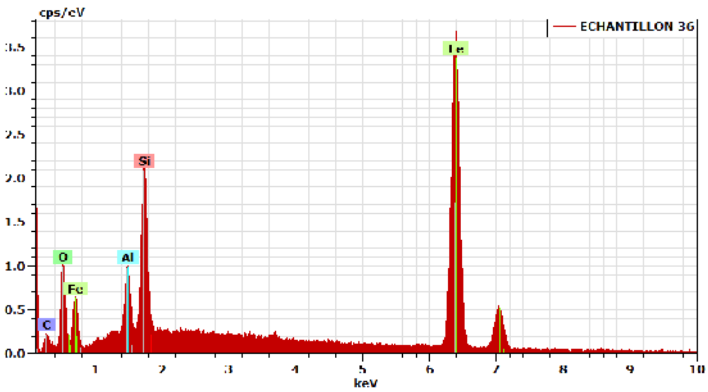


Figure.A_3. 2nd particle under SEM; scanned point shows fibrous goethite mass with quartz and clay material traces

A$_4$) B$_4$)

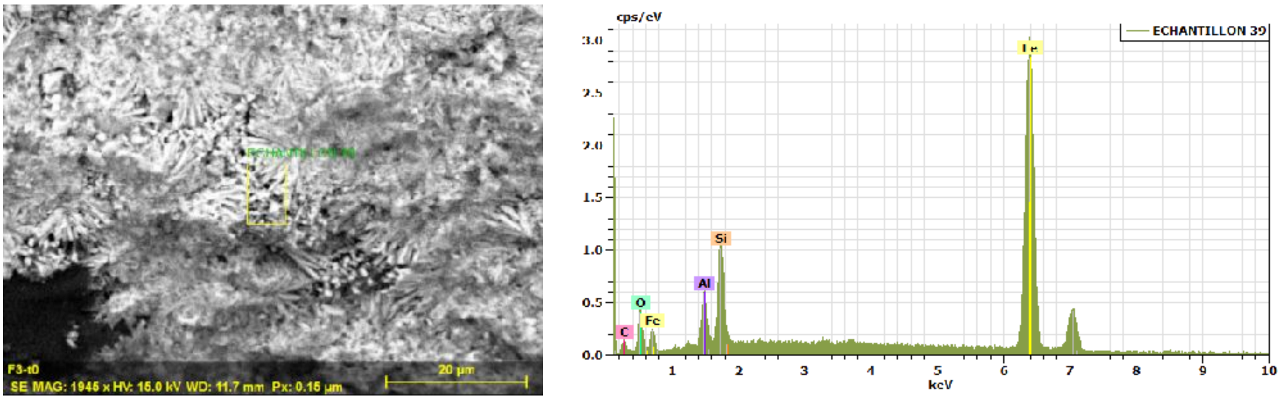


Fig.A$_4$. 3rd particle under SEM; scanned point shows quartz bathed in a hematite and goethite fibrous mass with presence of clay material traces

A$_5$) B$_5$)

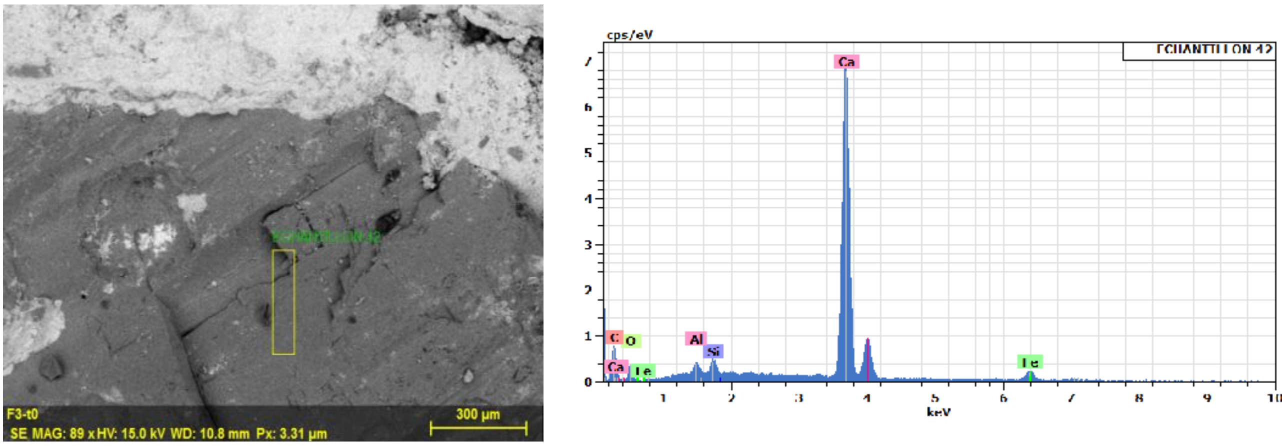


Fig.A$_5$. 4th particle under SEM; scanned point shows a calcite mass associated with hematite, quartz and clay material traces.

*Size analysis.*The results of the sieve analysis shown in Table 1 and Figure 9 show that the majority of the mass appears in the larger fractions [+2, +1, +0.5 and +0.25 mm] by 72.54% (486.47 grams), which confirms the iron ore hardness. The rest of the products appear in the finer fractions [+0.125, +0.063 and -0.063 mm].

Table.1. Results of particle size analysis of Rouina iron ore crushed to 5 mm

Size classes (mm)		Weight (g)	Yields (%)		
			Partial ∑γ	Passing cumulative ∑ γ↗	Refusing cumulative ∑ γ↙
-4	+2	281.77	46.96	100	0
-2	+1	89.42	14.91	53.04	46.96
-1	+0.5	64.03	10.67	38.13	61.87
-0.5	+0.25	51.25	8.54	27.46	72.54
-0.25	+0.125	50.72	8.45	18.92	81.08
-0.125	+0.063	41.44	6.91	10.47	89.53
-0.063	+0	21.37	3.56	3.56	96.44
TOTAL		600	100	/	/

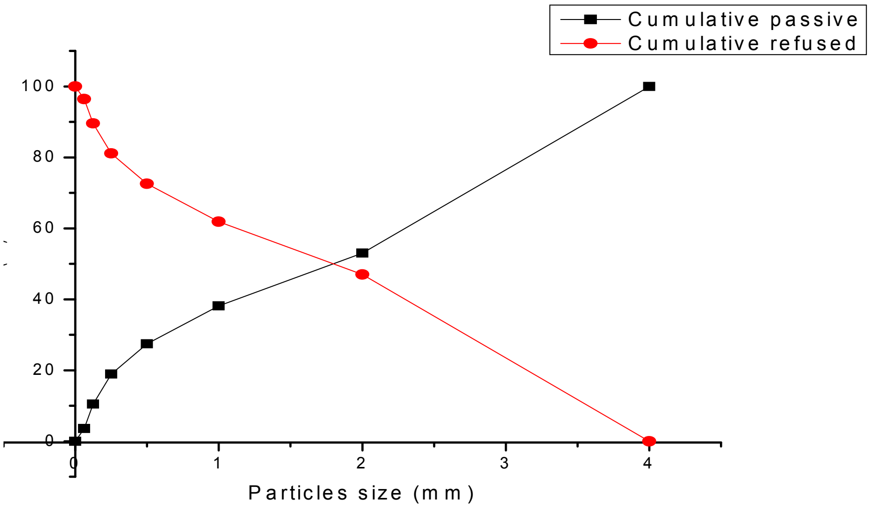


Fig.9. Graphical representation of particles size analysis results

Washed size classes.

XRD Analysis. The results shown in Figures 10 (a, b and c) prove that the washed size classes constitute essentially of iron oxides and calcite as a major component. However, few traces of quartz and illite are noted, confirming the effectiveness of washing in the reduction of the proportion of clay.

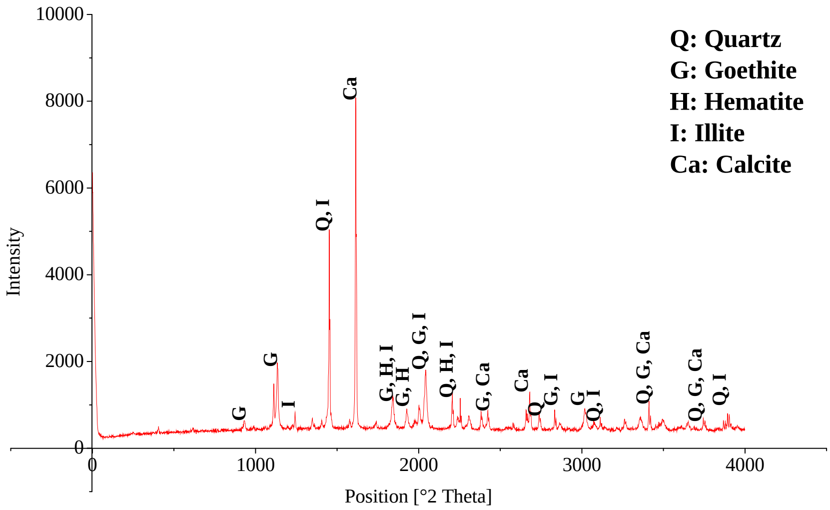


Fig.10.a: Diffractogram of size class [-1 +0.5 mm]

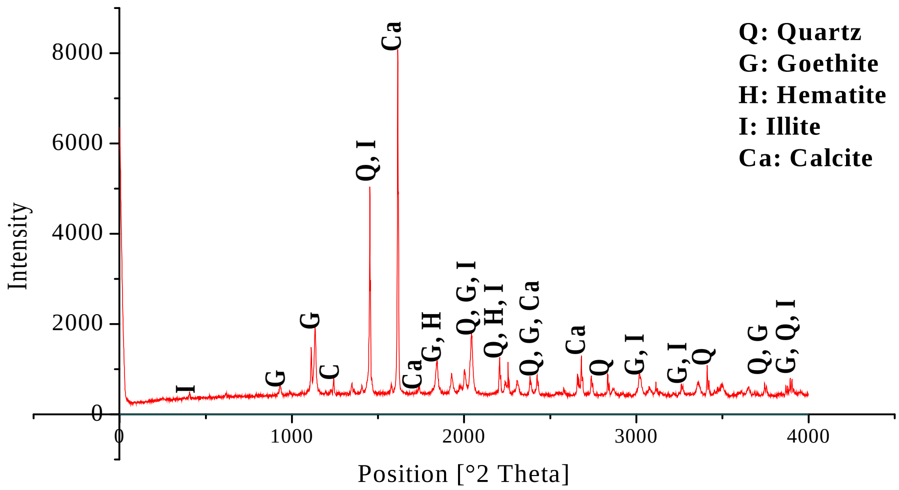


Fig.10.b. Diffractogram of size class [-0.5 +0.25 mm]

*XF Analysis.*The chemical analysis results of different size classes before and after washing are shown in Table 2. It is noted that the proportion of clay decreased after washing for the fraction -1 + 0.5 mm, it is also noted that the iron content was 51.03% against 44.18%, in the unwashed raw ore . Similarly, the alumina content decreased from 7.87% to 1.45%. The findings presented in Table 2 confirm the effectiveness of the washing process.

Table.2. FX analysis of the products before and after washing

Fraction (mm)	Process	Fe_2O_3	SiO_2	Al_2O_3	CaO	MgO
-1 +0.5	before washing	44.18	23.13	7.87	6.53	1.13
	After washing	51.03	24.20	1.45	7.57	0.40
-0.5 +0.25	before washing	43.78	22.26	6.96	6.22	1.06
	After washing	46.62	24.19	1.78	8.22	0.47
-0.25 +0.125	before washing	46.44	18.09	8.48	3.73	1.91
	After washing	41.99	30.81	1.96	7.69	0.59
-1 +0.125	before washing	45.44	22.06	7.53	5.08	1.45
	After washing	46.12	26.25	1.64	7.62	0.50

*Sludge XF Analysis.*It isnoted that rejects from the washing operation contain a high content of clays against a low content of iron oxide, whichmakes it possible to be used in other fields such as the cement and ceramic industry.

Table.3. FX analysis of the rejects from the washing test

Fe_2O_3	SiO_2	Al_2O_3	CaO	MgO
28.97	15.37	22.02	0.33	3.45

Proposed enrichment diagram. The suggested preparation and pre-treatment diagram of Rouina iron ore are presented in Figure 11; this proposed scheme allows one to obtain a pre-concentrate, which will be subsequently enriched. It permits also the recovery of water for reuse in the washing step. The rejects obtained (+1 mm and dried sludge) will be used in cement production.

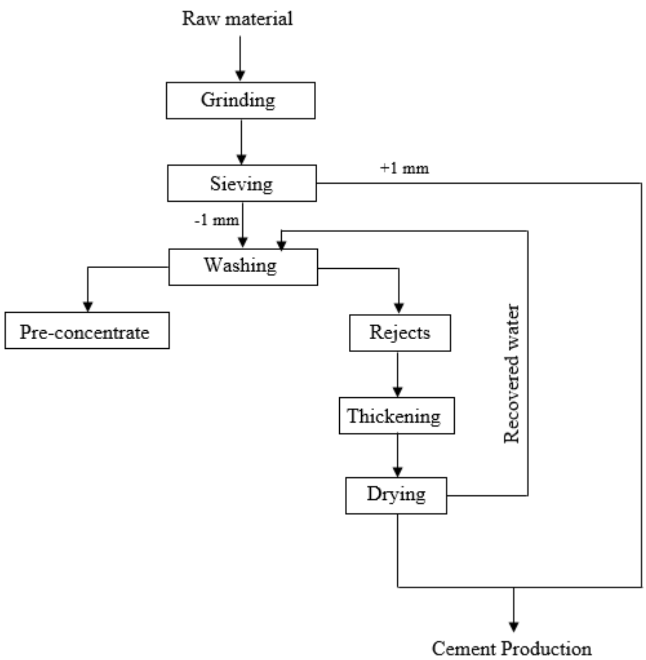


Fig.11. The proposed scheme of iron ore pre-treatment

Conclusions. The experimental results in the present study lead to the following conclusions:

1) The Rouina iron ore is classified as a low-grade clayey iron ore, which contains hema-

tite and goethite as useful minerals with quartz, calcite and clays as gangue minerals.

2) Application of washing as a preliminary enrichment method is effective for decreasing clay content and other associated gangue minerals (calcite and quartz) from the raw material, where the results obtained from the chemical analysis show a significant decrease in clay percentages after washing. It is also noted that the iron content is 51.03% against 44.18% in the raw material before washing. Similarly, the content of Al_2O_3 decreases from 7.87% to 1.45%, which confirms the significant results obtained by this preliminary enrichment (wet sieving).

3) On the one hand, the sludge residue from the washing process will be used as an adjuvant in the cement industry and on the other hand, the pre-concentrate will be enriched with the aim of recovering the maximum of useful minerals and obtaining a high-grade concentrate.

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- Boustila Amir, PhD student, Mining Department, Earth Sciences Faculty, University of Badji Mokhtar –Annaba- Algeria.

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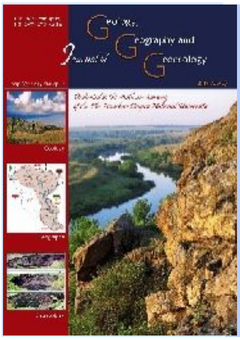

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Paleoenvironmental reconstruction of the Pleistocene site of Oued Sarrat (Northwestern Tunisia) using mineralogical and geochemical data

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Abstract. The mineralogical and geochemical analyses of Pleistocene sediments and mollusks shells (gastropods and bivalves) from the archaeopaleontological site of Oued Sarrat (Tejerouine, NW Tunisia) permitted us to determine the paleoenvironmental conditions and to reconstruct the local depositional environment during the Middle and Late Pleistocene. The mineralogical cortege of the sediments, for all the analyzed samples, records the characteristics of a mixture of silica and calcite dominance with a small fraction of gypsum and aragonite. The mineralogical analyses of all mollusk species reflect a cortege dominated by aragonite, associated with low amounts of calcite, silica, hematite and goethite. We consider that the dominance of aragonite indicates that the tests have not yet or little undergone mineralogical transformations linked to the phenomena of fossilization, as evidenced by the absence or low calcite content. On the other hand, the low percentages of silica, goethite and hematite are probably related to the existence of impurities and sediments trapped in lodges, or adhered to the shell surface. The mineralogical data confirm a composition dominated by calcium carbonates, expressed by high contents of CaO and CO_2, reflecting a chemical test of organisms' development in continental environment.This kind of environment is characterized by the absence of MgO, which is usually present in the organisms' tests developed in marine environment. However, the contents of SiO_2, Fe_2O_3, Al_2O_3 are related, as it was reported during the mineralogical study, to the lithological impurities trapped mainly in the lodges of helicides. Mineralogical and geochemical data tracing, carried out on sediments and tests, converge to deduce the establishment of paleoenvironment attributable to fluvial deposition of sufficiently high energy where the ultrafine fractions of clay minerals are remarkably lacking. The absence of indicators of marine chemistry such as magnesium in sediments and in the tests of organisms confirms almost total contribution of the continental meteoric water without marine influence. Such environment, however, is affected by intermittent episodes of aridity as attested by the presence of evaporate minerals such as gypsumand aragonite.

Key words:Environment reconstruction, Geochemistry, Mineralogy, Pleistocene, Oued Sarrat, Tunisia

Палео-екологічна реконструкція плейстоценового місцезнаходження Оуд Саррат (північно-західний Туніс) з використанням мінералогічних та геохімічних даних

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Анотація. У мінералогічному та геохімічному аналізах плейстоценових осадів та черепашок молюсків (черевоногих та двостулкових) з археопалеонтологічного об'єкта Оуд-Саррат (Тейчеруін, Північний Туніс) дозволили визначити палеоекологічні умови навколишнього середовища та реконструювати локальне осадове середовище протягом середнього та пізнього плейстоцену. Мінералогічна послідовність відкладів для всіх аналізованих зразків фіксує характеристики суміші кремнезему та домінуючого кальциту із незначною кількістю гіпсу та арагоніту. Мінералогічний аналіз усіх видів молюсків відображає послідовність, в якій домінують арагоніт, пов'язаний з низькою кількістю кальциту, кремнезему, гематиту та гетиту. Ми вважаємо, що домінування арагоніту вказує на те, що досліджені зразки ще не зазнали або зазнали незначних мінералогічних перетворень, пов'язаних з явищами літифікації, про що свідчать відсутність або низький вміст кальциту.З іншого боку, низький вміст кремнезему, гетиту і гематиту, ймовірно пов'язаний з існуванням змішування і захоплення осадів у базальному шарі, або прикріплення до поверхні оболонки черепашки. Мінералогічні дані підтвердили склад, в якому переважають карбонати кальцію, що відбивається високим вмістом CaO і CO_2 та відображає хімічний склад організмів, які розвивалися у континентальних умовах. Цей вид середовища характеризується відсутністю MgO, який зазвичай присутній у досліджуваних організмах, що розвивалися у морському середовищі. Однак вміст SiO_2, Fe_2O3, Al_2O_3 є пов'язаним, як встановлено мінералогічними дослідженнями, літологічно неоднорідними сумішами в норках геліцидів. Досліджені мінералогічні і геохімічні дані, які отримані по осадах і зразках, свідчать про встановлення особливостей палеосередовища у зв'язку із флювіальними потокамидостатньо високої енергії, в яких суттєво бракує надтонких фракцій глинястих мінералів. Відсутність у осадах і зразках організмів індикаторів утворення їх у морському середовищі, таких як магній, підтверджують майже повне привнесення континентальної атмосферної води без впливу морської. Втім, таки умови екологічного середовища зумовлені впливом періодичних епізодів аридизації клімату, про що свідчить присутність такого евапоритового мінералу як гіпс.

1. Introduction. The archaeopaleontological site of Oued Sarrat (Tejerouine, NW Tunisia) was discovered in 2014 and a large amount of vertebrate data was added for North Africa, with a special discovery of the aurochs *Bos primigenius* (Martínez-Navarro et al., 2014) and *Canis othmanii (*Amri et al., 2017). The Quaternary continental molluscs from this site were studied for the first time by Karoui-Yaakoub et al. (2016). Here we present mineralogical and geochemical data obtained from the Pleistocene sediments and molluscs tests (gastropods and bivalves) of Oued Sarrat with the aim of reconstructiing the Middle and Late Pleistocene paleoenvironments of the Oued Sarrat basin.

2. Geographical and geological setting. Oued Sarrat is located in the northwestern part of Tunisia, 10 km southwestwards from the Tajerouine (Fig.1). This region belongs to an intermediate zone between the Central and the Northern Atlas of Tunisia, with diapirs and rifts. It is dominated by folded structures interspersed with rift basins corresponding to the kalaa el Khasba and Rouhia Depression.

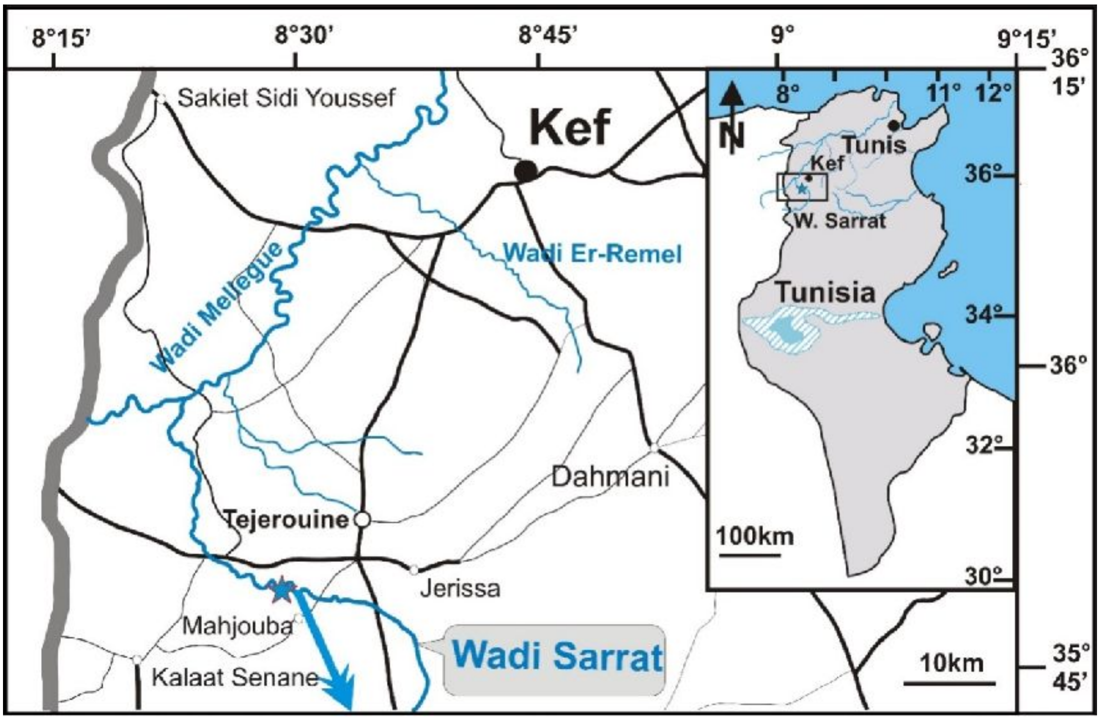

Fig. 1. Geographic location of the study area

The Pleistocene series of Oued Sarrat are composed of three units (Fig. 2). At the base, there are four meters of gray-black marl (OS1 and OS2). This layer is rich on vertebrate fauna, in particular *Bos primigenius* and *Canis othmanii*.This level is dated as beginning of the Middle Pleistocene (~0.7 Ma) by magnetostratigraphy and the presence of fossil remains of rodents (Martínez-Navarro et al., 2014; Mtimet et al., 2014). It should be noted that these marls are rich in invertebrate fossils, specifically gastropods and bivalves.

Above, a second clay level (2m) overcomes the first black level unconformably. It is less compact and dated to the Late Pleistocene (OS3). This level is rich in invertebrate fossils – bivalves (*Unio ravoisieri*) and gastropods (*Xerosecta cespitum, Cernuella virgata, Eobania vermiculata, Helix melanostoma, Sphincterochila baetica, Rumina decollata*) (see Amri, 2014; Bejaoui, 2014; Marti-nez-Na-varro et al., 2014; Mtimet et al., 2014; Ka-roui-Yaakoub et al., 2016; Amri et al., 2017).

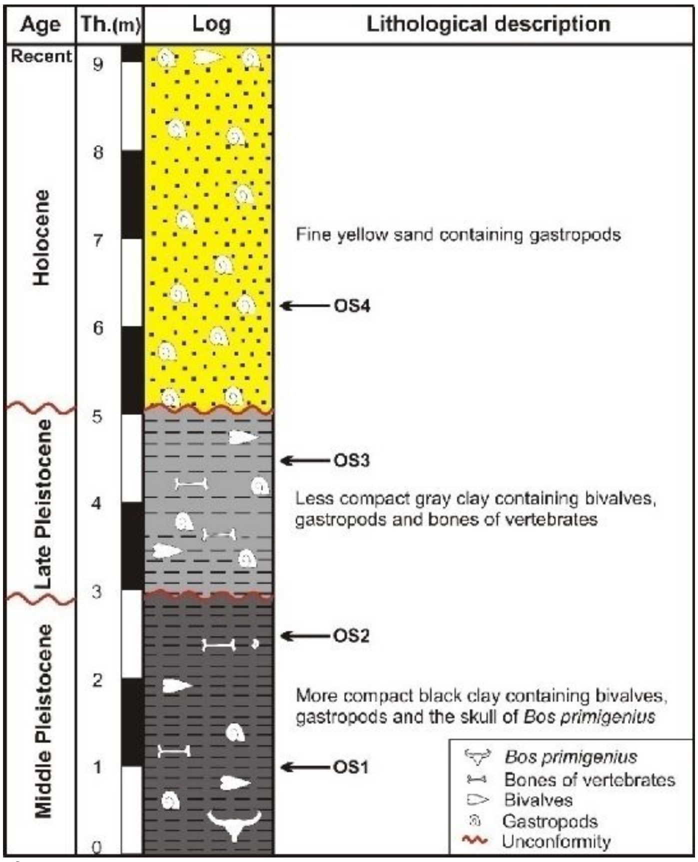

Fig. 2. Stratigraphic synthesis of the Oued sarrat series (in Karoui-Yaakoub et al., 20116)

At the top of the section (Fig. 3), a second disconformity is registered by the deposition of the third level, yellow to slightly brownish marl about 4 m in thickness (OS4). It yielded gastropods of Holocene age (Martínez-Navarro et al., 2014; Karoui-Yaakoub et al., 2016).

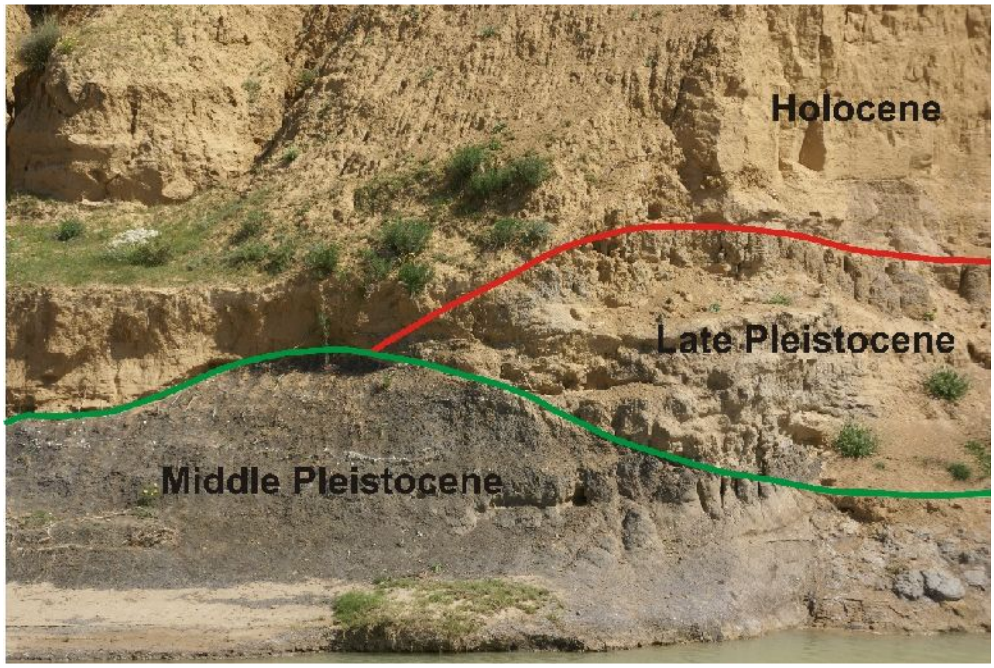

Fig. 3. The unconformity between the Middle and Late Pleistocene and between the Late Pleistocene and Holocene (Martínez-Navarro et al., 2014)

3. Materials and methods. Shells of gastropods and bivalves were sampled following the described Middle and Late Pleistocene stratigraphic series, which is outcropped on both sides of the Oued Sarrat.

The mineralogical and geochemical studies were performed on clay sediments from three levels yielding malacofauna. Two samples (OS1 and OS2) come from the Middle Pleistocene level, one sample (OS3) – from the Late Pleistocene level, and another one (OS4) – from Holocene marls.

4. Results of the study

4.1. Mineralogical cortege

4.1.1. Mineralogy on bivalves and gastropods

The results of mineralogical analyses of all registered mollusc species reflect a cortege dominated by mineral aragonite associated with low amounts of calcite, silica, hematite and goethite (Tab. 1, Fig. 4).

Table 1. Mineralogical composition of mollusk shells of Oued sarrat

	FeO3% Hematite	$CaCO_3$% Aragonite	$CaCO_3$% Calcite	FeO(oh)% Goethite	SiO_2% Quartz
Xerosecta cespitum	0.132%	92.90%	0	0	5.99%
Cernuella virgata	4.19%	89.57%	0	0	5.44%
Eobania vermiculata	4.70%	84.26%	0	0	9.97%
Helix melanostoma	2.34%	74.48%	10.54%	0	6.21%
Sphincterochila baetica	0	90.89%	0	7.89%	0
Rumina decollata	0.20%	82.48%	9.50%	0	0
Unio ravoisieri	0.18%	89.33%	0	0	4.13%

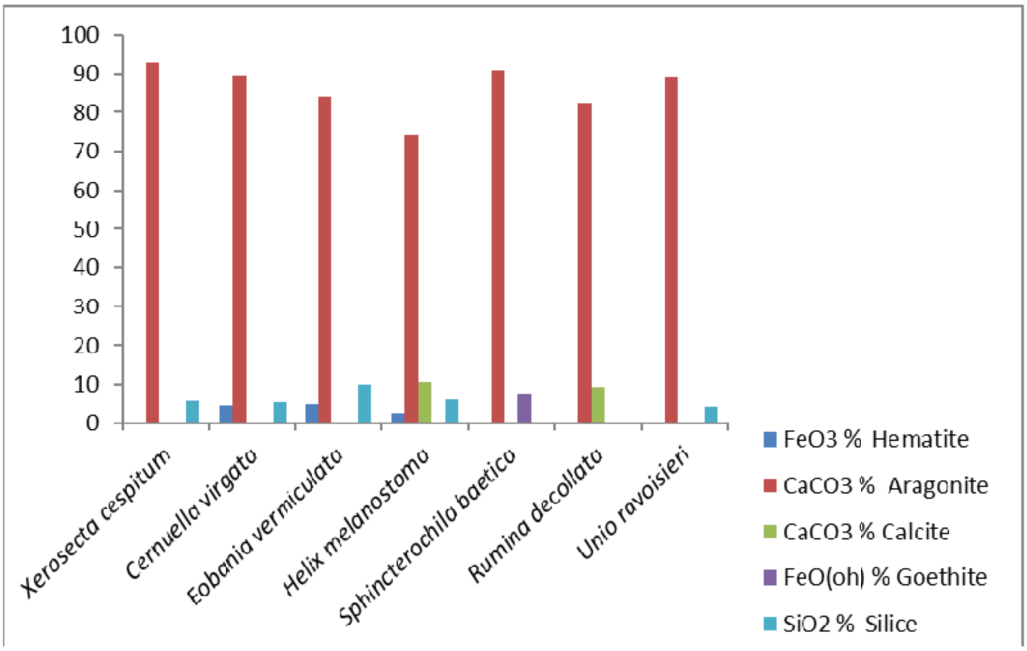

Fig. 4. Histogram of mineralogical composition of mollusk shells of Oued sarrat

We consider that the abundance of aragonite indicates that the shells have not yet undergone mineralogical transformations related to fossilization phenomena as evidenced by the absence or low content of calcite. We interpret the presence of traces of silica, goethite and hematite as due to the existence of sediment trapped in the dressing or binding to the surface of the shell.

4.1.2. Sediment mineralogy

The mineralogical cortege of the sediments, for all the analyzed samples, records a mixture of silica and calcite dominance containing a small fraction of gypsum and an aragonite fraction of 11.65% in the sample OS4 (Tab.2, Fig.5). The calcite-silica reflects initially the characteristics of a detrital sediment in which calcite is likely related to lithoclastic fragments with low contribution of aragonitic debris, as evidenced by the low content of aragonite in the sample OS4.

Table 4. Chemical composition of clays in Oued sarrat

	CaCO3% Aragonite	CaCO3% Calcite	Al2O3%	FeO(oh)%	CaSO4%	SiO2%
OS1	0	40.27	1.12	7.65	3.57	36.53
OS2	0	43.31	2.94	5.54	3.66	29.05
OS3	0	51.89	2.78	7.95	0	27.20
OS4	11.65	34.12	0	6.65	0	18.98

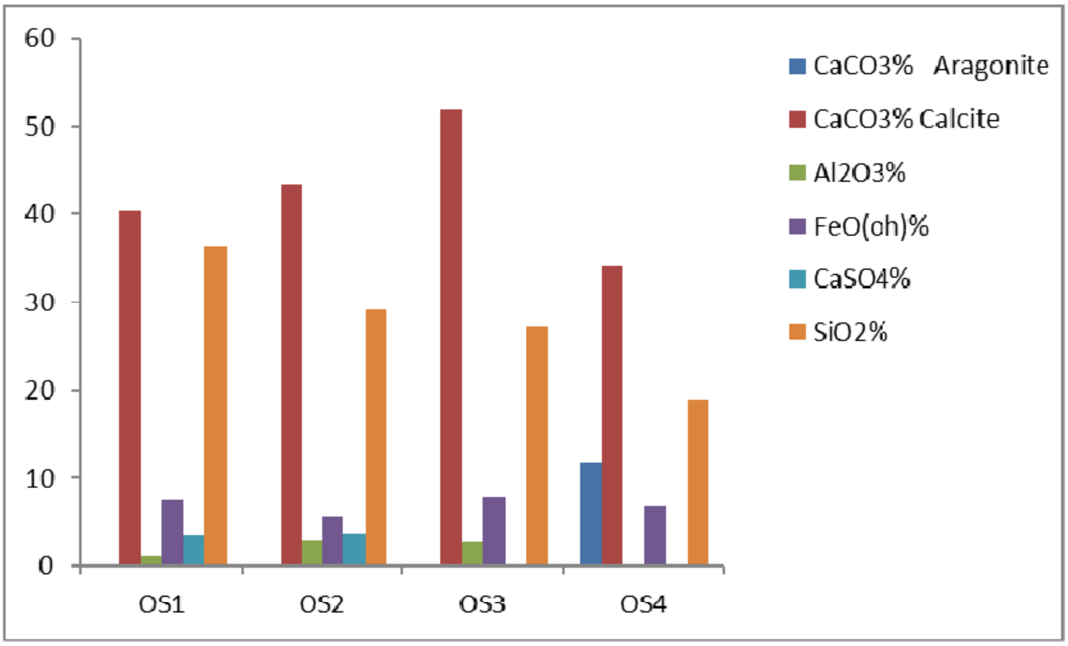

Fig. 5. Histogram of mineralogical composition of marl of Oued sarrat

4.1.3. Interpretation

The absence of clear clayey minerals signals in the analyzed spectra, as well as the abundance of calcified siliceous fraction, reflects a fairly high-energy fluvial environment undergoing at times of arid conditions favorable to the formation of evaporitic minerals.

4.2. Geochemical tracing

4.2.1. Analysis on shells of gastropods and bivalves

The results presented in Table 3 confirm the mineralogical data with a composition dominated by calcium carbonates, expressed by high contents of CaO and CO_2. This reflects a chemical test on development of organisms in a continental environment clearly confirmed by the absence of MgO, which is usually present in the organisms' tests developed in a marine environment, with an Mg content varying from 12 to 18%. However, it should be noted that in Pleistocene tests for the species *Unio ravoisieri*, the Mg content is equal to zero, although the analysis of the extant species shows that this values is equal to 2.31% (Tab.3, Fig.6). This low Mg content is far from reaching the characteristic values of completely marine species. This Mg rate could be linked to a certain ability of the species to obtain this element from the fluviatile waters. This ability indicates a possible change in the behaviour of above mentioned species. On the other hand, the contents of SiO_2, FeO_3, Al_2O_3, are also comparable, as it was reported during the mineralogical study, to the lithological impurities trapped mainly in the lodges of helicides.

Table 3. Chemical composition of Pleistocene mollusk shells of Oued sarrat

	CaO %	Al2O3 %	CO2 %	Fe2O3 %	SiO2 %	MgO%
	Pleisto	Pleisto	Pleisto	Pleisto	Pleisto	Pleisto
Xerosecta cespitum	53.53	3.74	37.17	0.12	5.45	0
Cernuella virgata	51.60	3.31	36.21	3.86	5.01	0
Eobania vermiculata	49.21	3.87	33.61	4.27	9.05	0
Helix melanostoma	48.84	1.07	36.95	4.79	5.73	0
Sphincterochila baetica	52.29	3.33	36.72	6.88	0.00	0
Rumina decollata	56.16	1.31	42.38	0.16	0.00	0
Unio ravoisieri	52.50	5.05	34.65	3.66	0.00	0

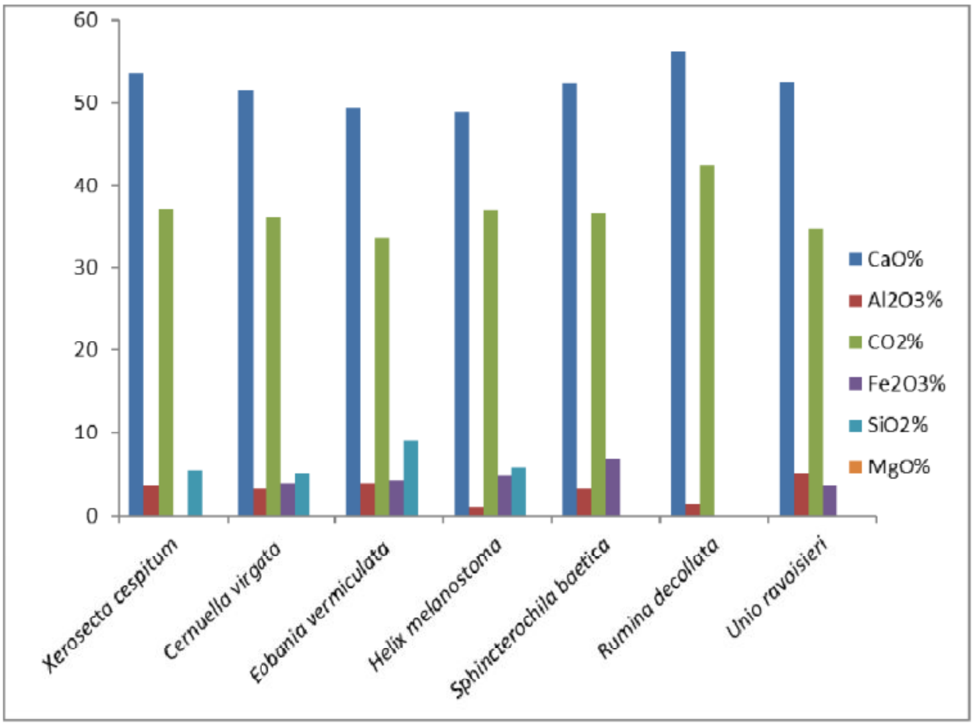

Fig. 6. Histogram of chemical composition of Pleistocene mollusk shells of Oued sarrat

4.2.2. Sedimentological analysis

The results presented in Table 4 reflect the original sand-calcitic and detrital sediments exceeding 90% for this fraction. Coupled with very low proportions of Al_2O_3, about 3%, all data allow us to assume a fluvial environment where the water winnowing seems to be unfavorable to the sedimentation of the ultrafine fraction of the clayey minerals. The continental chemistry is demonstrated by the absence of magnesium in all analyzed sediments (MgO = 0; Tab. 4, Fig. 7).

Table 4. Chemical composition of clays in Oued sarrat

	CaO %	Al2O3 %	CO2 %	Fe2O3 %	SO3 %	SiO2 %	MgO%
OS1	35.85	0.85	26.96	5.17	2.14	27.49	0
OS2	35.38	2.94	26.87	4.84	1.63	27.05	0
OS3	35.64	3.51	26.78	8.10		25.25	0
OS4	41.66		32.68	5.98		18.98	0

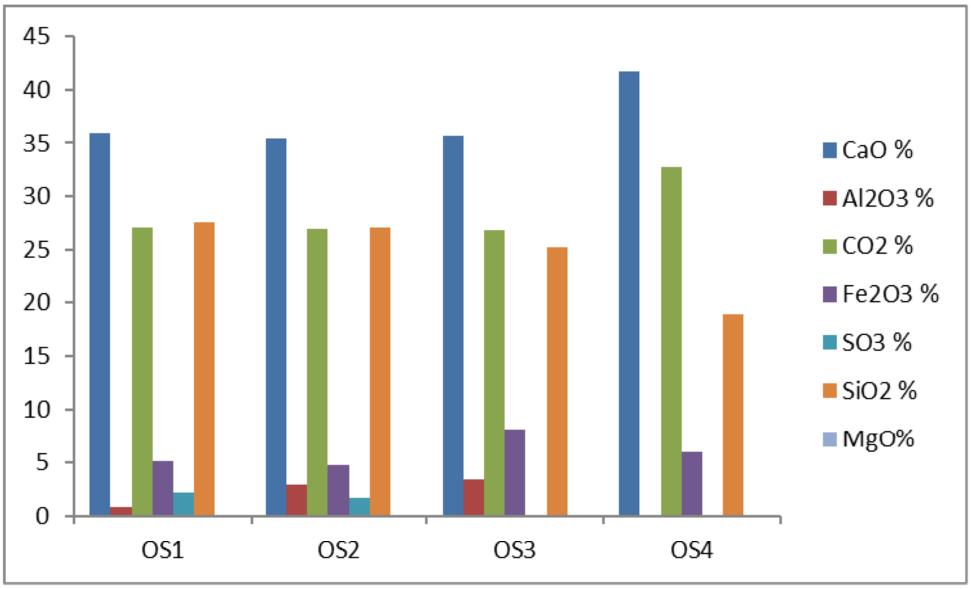

Fig.7. Histogram of chemical composition of clays in Oued sarrat

4.3. Interpretation of mineralogical and geochemical data

Mineralogical and geochemical data tracing, carried out on sediments and tests, allow us to conclude the establishment of a paleoenvironment attributable to fluvial deposition of sufficiently high energy where the ultrafine fraction of clayey minerals is remarkably lacking. The absence of indicators of marine chemistry, such as magnesium, in sediments and in the molluscs' tests confirms the almost total contribution of the continental meteoric waters without marine influence. Such environment, however, is affected by intermittent episodes of aridity as evidenced by the presence of evaporates such as gypsum.

5. Conclusion

Mineralogical and geochemical analyses confirm previously obtained paleoecological results (Martinez-Navarro et al., 2014; Karoui-Yaakoub et al., 2016; Amri et al., 2017). The depositional environment was definitely neither marine nor lagoonal, but rather fluvial due to continental meteoric waters in a hot climate.

The Oued Sarrat site is dated in time frame from the Middle to the Late Pleistocene, a landscape covered with swamp and forest, or even shallow freshwater lake. The latter was powered by channels and, certainly, around the lake there inhabited abundant different large mammalian species together with other small vertebrates and invertebrates that were probably consumed for human survival.

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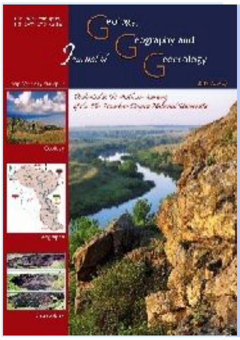

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Recreational skiing in the formation of local settlement systems of Prykarpattya region

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Abstract. The formation of local settlement systems is considered on the example of mountainous areas of Ivano-Frankivsk region (Ukraine), so-called Prykarpattya region, and is based on a complex set of factors. Recreational skiing plays an important role in the functioning and development of such systems and is simultaneously an integral part of them. The settlement systems in the mountainous areas of Ivano-Frankivsk region, which are based on recreational skiing are highlighted and investigated, in particular they are: the Kosiv system, the Yaremche-Vorokhta system (consisting of two subsystems of the Yaremche and Vorokhta -Yablunytsya), the Verkhovyna system and autonomous centers of recreational skiing in the villages Vyshkiv and Guta . Their detailed profile in demographic terms, including migration processes; natural resource possibilities; socio-economic potential and interaction with recreational skiing is outlined. The methodological principles of the spatial structure formation of local settlement systems are based on the following states of the system approach: - the main territorial-planning elements of the systems are defined: skiing complexes (one large enterprise or a group of enterprises) with a ski area and a development zone; center of the system, which is a tourist center with services, production and transport; settlements with rural territories and enterprises of the agro-industrial complex; valuable landscape (national parks, nature reserves); focal points of tourist destinations;- functional and spatial associations of ski recreation facilities with settlements, recreational, natural and nature-protected areas, and engineering-transport infrastructure are established;- the approximate boundaries of systems are determined on the basis of spatial, functional and labour relations, types of their territorial-spatial structure, distances between settlements accepted within the radius of one hour transport accessibility.Planning types, directions and trends of development and spatial transformation of local settlement systems with recreational skiing are identified. The role and significance of local settlement systems with recreational skiing as an urban planning object is demonstrated within the general system of recreational zoning.

Key words: local settlement systems, recreational skiing, spatial structure of resettlement

Гірськолижна рекреація у формуванні локальних систем розселення Прикарпаття

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Анотація. Формування локальних систем розселення, розглянутих на прикладі гірських районів Прикарпаття (Івано-Франківська область, Україна) відбувається на основі складного комплексу чинників, серед яких гірськолижна рекреація відіграє провідну роль у функціонуванні і розвитку таких систем та одночасно є їх складовою. Виділено і досліджено системи розселення в гірській частині Івано-Франківської області, які розвиваються на базі гірськолижної рекреації, а саме: Косівську, Яремчансько-Ворохтянську (до складу якої входять дві підсистеми Яремчанська і Ворохтянсько-Яблуницька), Верховинську та автономні осередки гірськолижної рекреації в с. Вишків і в с. Гута. Подана їх детальна характеристика за демографічною ситуацією, в тому числі міграційними процесами; природно-ресурсними можливостями; соціально-економічним потенціалом та взаємодією з гірськолижною рекреацією. Розроблені методичні засади формування територіально-просторової структури локальних систем розселення на основі положень системного підходу. Визначено типи планувальних структур, напрямки і тенденції розвитку й просторової трансформації систем розселення . Показано роль і значення систем розселення з гірськолижною рекреацією як об'єкта містобудівного проектування у загальній системі рекреаційного районування.

Ключові слова: локальна система розселення, гірськолижна рекреація, територіальна структура розселення

Introduction. Nowadays recreational skiing is one of the most popular types of winter recreation. Its popularity is attested by the construction of new ski resorts and other objects connected to this form of recreation in mountains, and their spread throughout the world.

Ski resorts or sets of recreational skiing objects function in settlement systems of different hierarchical ranks – regional, district and local. The closest connections between recreational skiing objects exist within a limited local area because of the common use of recreational potential of the territory, infrastructure, workforce and socio-economic base of the settlements, which are subordinated to self-government bodies and territorial communities.

The formation of local settlement systems is considered on the example of Ivano-Frankivsk region (Ukraine), which consists of six mountainous areas. These areas differ in the amount of recreational skiing objects of different capacity, natural resource potential, socio-economic development of the settlements and infrastructure.

Recreational skiing as a leading branch of economic activity of closely located and interconnected settlements (local settlement systems) creates the base for the production activity of the population, increases the chances of introducing other additional sectors of tourist servicing, thereby exercising the mutual influence of mountain recreation and settlement systems.

Investigation of recreational territories is highlighted in numerous works of researchers covering a wide range of problems in the spheres of geography, economics, social ecology, urban planning, etc. In Ukraine, a thorough basis of settlement systems research was laid out by the urbanist researchers: Y. Bilokon, I. Fomin, M. Kushnirenko, M. Dyomin, M. Habrel, I. Rusanova and others. The formation of territorial recreational systems was investigated by the urbanists T. Panchenko, V. Shulyk, V. Vladimirov, and also by geographers O. Preobragenskyi, V. Dgaman, A, Dotsenko, P. Maslyak, M. Palamarchuk, F. Mazur, O. Beidyk and others. Regional problems of the Ukrainian Carpathians, in particular landscape and urban problems, resource base, historical and cultural potential, were explored by T. Panchenko, M. Habrel, Y. Taras, H. Petryshyn, G. Shulga and others. The influence of various types of recreation, and in particular recreational skiing, on the activation of the development of settlements of the Carpathian region is discussed by scientists: M. Greta, T. Kostrzewa-Zielinska, J. Mirek, A. Ilieş, D. Ilieş, O. Dehoorne.

In recent years on the initiative of the European Union and with the participation of Ukraine, mountainous areas development programmes and strategies have been developed and implemented. One of them, "EU Macro-regional strategy for the Carpathian region" (Szuba, 2017) determines the modern directions of development of this region, which mainly concerns higher-ranking systems. This work has not paid attention to the formation of settlement systems at the local level with the specificity of solving problems and taking into account the features of the territorial planning on the basis of recreational skiing.

The aim of this study is to develop criteria and mechanisms for the formation of local settlement systems on the basis of recreational skiing in the mountainous areas of the Carpathians (on the example of Ivano-Frankivsk region) and to determine the principles for improving their territorial organisation and development.

Material and methods. The research is based on the analysis of the research publications and project materials in relation to this topic, as well as on field surveys of 13 ski resorts in the mountain districts of Ivano-Frankivsk region.During field surveys the capacity of ski resorts, the quantity and quality of their services, their role and significance beyond and within the boundaries of the state, region and district were determined (Onufriv, 2017).

During the study of individual settlements, statistical data, empirical methods and content analysis of the theory and practice of recreation formation in resettlement systems were used. In the survey of ski recreation objects and settlements within the studied territory, cartographic materials were used.

The basic method of research is system analysis and principles of system formation, where at the lowest level - the local system, interconnected settlements are considered as a single organism with territorial-production, cultural and economic, transport, tourist and recreational links.

Results and discussion. On the Ukrainian territory of the Carpathians, the Prykarpattya region is distinguished as a separate region with the predominant function of mountain recreation. Part of Ivano-Frankivsk region is fully part of Prykarpattya, and this is almost 50% of the area of the region with mountain ranges: the Eastern Beskydy, Gorgany, Pokutski mountains, and separately - the ranges of Chornogora with the highest peak of Hoverla. Establishment of settlements in these areas is traced to the 16th-17th centuries, and the population consists mainly of Ukrainian-highlanders - Hutsuls with their rich culture, customs, architecture, which is reflected in the specifics of these mountainous regions.

Since ancient times, natural conditions have made this region a tourist pilgrimage area, which later became the place of recreational skiing on a large scale- the main direction of economic activity and socio-economic development of local settlements.

The recreational attractiveness of this area lies not only in the natural-landscape conditions and picturesque landscapes, but also in its geographical po-sition on the border with Romania, through which the tourist routes to Bulgaria, Serbia, Montenegro, and Greece are laid.

A group of recreational facilities (or one object) create their own zone of influence associated with the zoning of the recreational area. In this case, the concept of "recreational territory" is treated as a component of the land fund with a system of interconnected natural, natural-social and social components (Beidyk, 2001). The methodology of taxonomic zoning of recreational territories is considered by T. Panchenko (2009) at the level of the region, district, tourist area, taking into account the area of the recreational territories. Specialists use different criteria for zoning of territories, reflecting the spatial dispersion of recreational resources . According to V. Shulyk (2007), a recreational area is a type of functional-branch zoning, which is based on recreational orientation. G. Shulga (2015) emphasizes the role of landscapes in the zoning of a territory. The proposed methodology of "landscape-spatial pools", which are territories limited by watersheds of different order, is attached to urban systems at the level of the region, zone, district, area.

The existing method of regionalisation of recreational territories does not give a clear definition of the size and subordination of taxonomic units of these territories, their connection with the settlement systems. A more objective definition exists for territorial-recreational systems in the territory of a certain taxonomic rank of the complex of recreational establishments based on the use of resources of this territory, spatially and territorially interconnected ones (Maslyak, 2008). Thus, the system concept of recreation, which includes the territorial integrity of the system with interconnected subsystems (natural resources, objects of historical and urban planning and cultural heritage, engineering infrastructure, service and management), is included in this definition; hierarchy (region, zone, district, territorial recreation complex). The territorial recreational complex can be regarded as a low link in such a hierarchy, represented by an object or a group of recreational facilities operating on a particular territory with natural and socio-economic characteristics. Objects of territorial recreational complexes provide a significant set of variants of territorial and economic system formation at different hierarchical levels. At the lower hierarchical level, recreational facilities (ski resorts) are located on a limited local area, establish close links with neighbouring settlements, providing not only recreational services, but also performing territorial functions through the sharing of natural, labour and other resources.

Ski complexes, as a rule, are combined with other types of recreation (from extreme to passive recreation), and aimed at their year-round operation regardless of the season. Mountain recreation spreads its influence on the surrounding settlements with their cultural-historical and ethnic characteristics, which provide a material base and service, and promote the attractiveness and multiplicity of mountain resorts. Due to such interconnections local settlements are formed, in which mountain recreation becomes the organizer of socio-economic development of settlements themselves and in the system.

Methodological aspects of the research on settlement systems that operate on a separate territory include the following factors: natural resources, socio-economic potential, demographic situation, migration processes in the formation of settlement potential (Dgaman, 2003). The general factors of formation affecting local systems of resettlement with recreational skiing are manifested in the identification of natural and recreational resources that contribute to the directions of the related types of recreation within such systems, the socio-economic and demographic situation of settlements for recreation services and infrastructure development. These same factors generally determine the spatial structure of systems.

The methodological principles of the formation of the spatial structure of local systems are based on the following states of the system approach:

- the main territorial-planning elements of the systems are defined: skiing complexes (one large enterprise or a group of enterprises) with a ski area and a development zone; center of the system, which is a tourist center with services, production and transport; settlements with rural territories and enterprises of the agro-industrial complex; valuable landscape (national parks, nature reserves); focal points of tourist destinations.

- functional and spatial associations of recreational skiing facilities with settlements, recreational, natural and nature-protected areas, and engineering-transport infrastructure are established.

- the approximate boundaries of systems are determined on the basis of spatial, functional and labour relations, types of their territorial-spatial structure, distances between settlements accepted within the radius of one hour transport accessibility.

Local settlement systems are not internally closed, but exist in the system of external connections, which are found not only in the flows of recreation, but also in the influence of the foreign economic situation of the state, region, and district.

The internal factors of the formation of systems determine the type of the system, the boundaries of its localisation, which depend on the nature and parameters of the system-forming elements (recreational institutions, their concentration and territorial combination), socio-economic and demographic conditions of settlements, and communication infrastructure.

Systems with recreational skiing are considered as those where the set of services is different from other recreational territories. In some of them, recreational skiing dominates other industries, while in others it is an important but not the major function.

Unlike areas in the plains, the processes of living in mountain settlements are greatly complicated due to the smaller amount of agricultural land, the small sphere of application of labour, poor accessibility of public services, etc. Prykarpattya is a densely populated and weakly urbanised region with a specific weight of urban population of 42.9%. The density of the village settlement network in the mountainous area is much smaller than in the lowlands, and at the same time the average population of a mountain village (1300 people / km2) is greater than that of the villages in the plains (946 people / km2) (Dotsenko, 2007).

The peculiarity of living conditions in mountainous areas is acknowledged in the State Law of Ukraine "On the Status of Mountainous Settlements" (Verkhovna Rada of Ukraine, 2005), which provides some privileges to mountain settlements, which are clearly insufficient for their stable development. The functioning of mountain settlements and, in particular, sparsely populated settlements, can be achieved by linking them to more developed district centers, small towns or urban-type settlements, which ensure their development as ski resorts. This goal also corresponds to the unification of territorial communities, which is taking place in Ukraine today, creating local resettlement systems. On the basis of territorial proximityof settlements, their close interrelationships, common use of natural and material resources, common touristic infrastructure in the mountainous areas of Ivano-Frankivsk region, the following local settlement systems based on recreational skiing are singled out: the Kosiv system, the Yaremche-Vorokhta system (consisting of two subsystems of the Yaremche and Vorokhta -Yablunytsya), the Verkhovyna system and autonomous centers of ski recreation in the Vyshkiv area and in Guta village. Placement of settlements relative to the main highways and secondary roads, their status, size, as well as the role in the system (center, sub-centers, specialised centers, settlements) determine the type of their planning structure (Fig. 1).

The analysis of local settlement systems in the mountainous areas of Ivano-Frankivsk region, based on the indicators of the demographic situation, the number and size of settlements with the presence in their composition of the ski resort facilities, shown in Table 1, revealed differences in their characteristics. Thus, the number of interconnected settlements (and hence rural communities) is combined into set-tlement systems of different sizes that do not correlate with the general density and percentage of urban and rural population (0.67%) than the average indicator (0.57%) in the region. This characteristic is supplemented by other factors: natural resources, urban conditions, labour potential, transport accessibility and a role of mountain recreation in a group of settlements. All these factors determine the specifics of each of the systems.

The Kosiv system (Fig. 2 A) is located in the foothills and lowlands of the Pokutsko-Bukovynian Carpathians, and has a linear-polycentric structure with a center in Kosiv, which lies on the highway of regional significance, which unites Verkhovyna, Vorokhta, Yaremche. This settlement system is distinguished by a rather high percentage of urban population and large populations of settlements. In the Kosiv area, there are three ski complexes that are weakly interconnected. In the town Kosiv and urban village Kuty most service facilities are centered. The largest settlement Pistyn, with a population of more than 4 thousand inhabitants, is located at the intersection of highways with a branch in Sheshory, has medical facilities and archeological remains. This system includes the national park "Hutsulshchyna", sanctuaries and protected tracts, and the settlements themselves form strands of resettlement along the roads. The multifunctionality of the system recreation, which is operated year-round, gives all grounds to consider it promising with high development potential.

The Yaremche-Vorokhta settlement system (Fig. 2 D) is divided into 2 subsystems. One of them consists of the city of the regional significance Yaremche and the historical settlements Mykulychyn and Tatariv, which form a linear structure on the highway of international significance. The center of this system in Yaremche is the oldest tourist center of the Carpathian region. The multi-occupancy of this resort is complemented by a ski resort with medium difficulty trails.

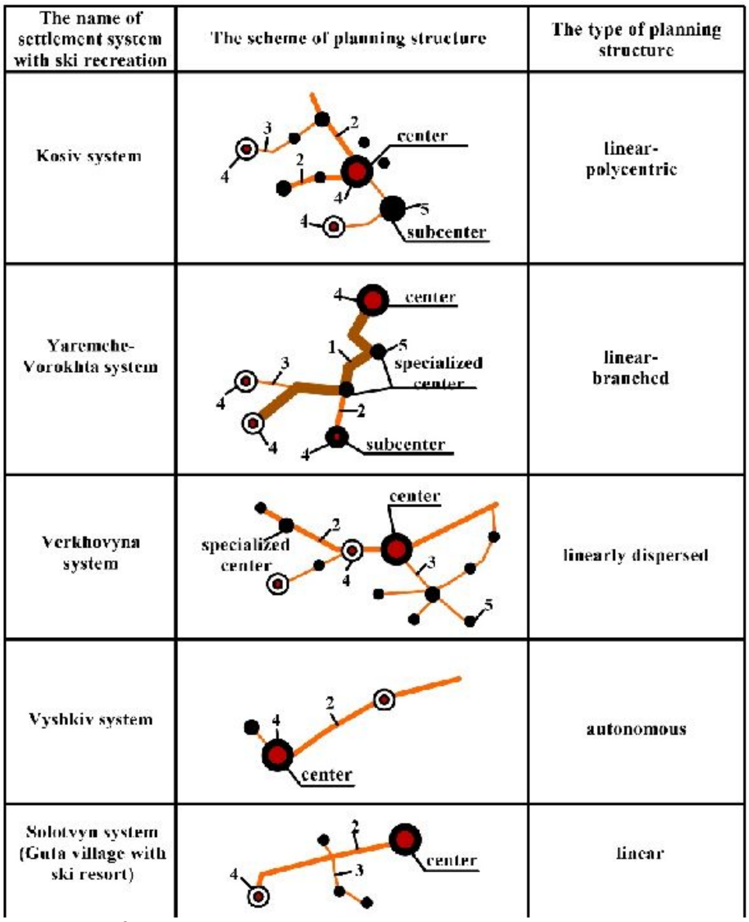

Fig. 1: Types of planning structures of local settlement systems with ski recreation: 1) - international highways; 2) - regional highways; 3) - roads of local importance; 4) - settlements with ski recreation; 5) - settlements (source: Iryna Rusanova, Iaryna Onufriv).

Tab. 1. Characteristics of local settlement systems of Prykarpattya (by the demographic situation and the presence of ski recreation facilities). Source: Main Department of Statistics in Ivano-Frankivsk Region, Ukraine (2017)

Local settlement systems		**Kosiv**	**Yaremche-Vorochta (1 – subsystem with the center in Yaremche**	**Yaremche-Vorochta (2 – subsystem with the center in Vorochta**	**Verchovyna**	**Vyshkiv**	**Solotvyn**
Number of	**towns**	1	1	-	-	-	-
	urban villages	1	-	1	1	-	1
	villages	12	3	3	11	3	6
The system center		Kosiv	Yaremche	Vorokhta	Verkhovyna	Vyshkiv	Solotvyno
Number of population	**total**	37651	17147	7182	20675	2001	14522
	center	8280	8168	4263	5872	651	3891
	urban, %	44	48	47	28	-	28
	rural, %	56	52	53	72	100	72
Population density (people/km^2)	**total**	200.63	332.60	258.20	35.40	12	130
	center	727.00	658.00	441.40	104.00	12.61	206.00
Ski recreation objects location		Kosiv, Sheshory, Tyudiv	Yaremche	Vorochta, Yablunytsya, Polyanytsya (Bukovel)	Verchovyna, Iltsi	Vyshkiv	Guta
Capacity of ski resort (people/day)		up to 450	450-1200	150-20000	450-1200	150-450	150

Located near Mykulychyn village with a population of about 5 thousand people, it has developed as a climatic resort. Tatariv village within the Carpathian National Nature Park on the banks of the Prut River can be considered as the most promising mountain resort due to the rich natural resources and geographical location on the highway leading to the largest ski resort Bukovel, village Yablunitsa and the urban village Vorokhta, forming a second subsystem with the center in Vorokhta near Yablunitsky Pass. The economic basis of the formation of this system, in addition to the multifunctional ski resort with tourist facilities, sports schools, health and recreational facilities, is livestock and plant cultivation, and industrial production on the basis of woodworking. This settlement system is an example of how recreational skiing with large scale skiing complexes contributed to the multiplicity of these settlement systems. Spa complexes, summer recreation by the water, quad bike rides and cycling complement the attractiveness of these complexes in the summer. The development in these areas of year-round recreational skiing complexes has led to the development of once remote peripheral settlements with the involvement of local residents in service recreation facilities, thereby providing them with work.

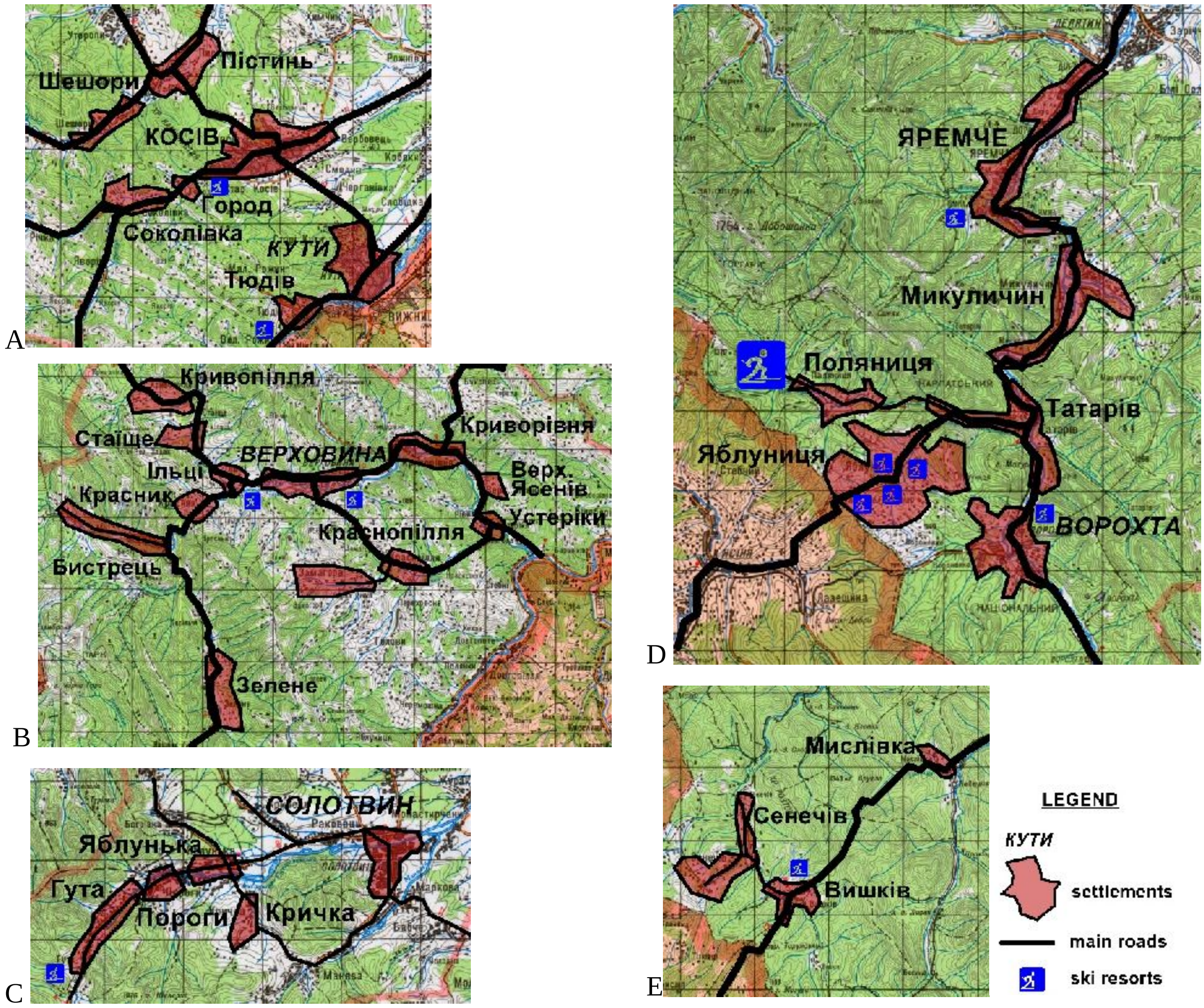

Fig.2: Local settlement systemswith ski recreation: A – Kosiv system; B – Verkhovyna system; C – Solotvyn system ; D – Yaremche-Vorokhta system; E – Vyshkiv system(source: Iryna Rusanova, Iaryna Onufriv).

The Verkhovyna settlement system (Fig. 2 B) is characterised by a low population density, located in a mountainous area with the highest peaks of the Eastern Carpathians. This resulted in a linearly dispersed planning structure stretching along the highway of regional significance with the center in the urban village Verkhovyna (until 1962 - it was called Zhabye) with the branching of a group of settlements along the Black Cheremosh River and in the south-easterly direction. Small ski resorts are concentrated in Verkhovyna and Iltsi, and such villages as Kryvorivnya (ethnographic and cognitive tourism), Kryvopillya, Bystrets, Zamagora are specialised centers of hiking tourism, Dzembronja - the center of rural and extreme tourism (Kryvoruchko, Korol, Ignatyuk, 2007). The multifunctionality of recreation contributed to the development of light and food industries in the settlements. Land resources, unfavourable for arable land, led to the development of livestock and logging.

The Vyshkiv settlement system (Fig. 2 E) includes the autonomous group of settlements in the mountainous area of the Dolynsky district - the village of Vyshkiv and Myslivka on the highway Lviv-Khust and the village Senechiv near the village Vishkiv. This is a sparsely populated area with the lowest population density in the region. However, the rich natural conditions, the location along the tourist routes along the road to Lake Synevir, Vyshkivsky and the Torunsky Pass have created a tourist center here with hotels, camps, ski infrastructure in Vishkiv and Myslivka. The recreational potential of this area is far from exhausted, which makes it possible to create new multidisciplinary ski resorts here.

Recreational skiing in Guta village, which is a part of the Solotvyn settlement system (Fig. 2 C), is not dominant. The settlements are mainly concentrated in the valley of the Bistrica river, where the population is mostly occupied in agriculture and forestry, which is the economic basis for the development of this system. Guta village is considered to be the residence of elite recreation, here a small ski complex "Sinegora" works, as well as the beginning of tourist hiking trails in the mountain range of Gorgany .

The results of the analysis of existing settlement systems showed their irregularity in size, number and density of population, natural and urban conditions, infrastructure, the degree of recreational potential development, socio-economic base. According to these indicators, the most developed systems are the Yaremche-Vorokhta, Kosiv and Verkhovina systems.

Determination of trends in the further development of settlement systems should be based on factors that reflect the specifics of mountain areas:

- natural conditions (mountain ranges, reservoirs, forests, national parks and nature reserves);
- recreational and tourist resources (availability and diversity of recreation, its capacity and attractiveness, conditions for all types of tourism);
- ecological (climate, lack of sources of air pollution, etc.);
- urban planning (number and size of settlements, transport infrastructure, the presence of links);
- demographic (population density, age and gender structure, migration processes, etc.);
- economic (recreational sphere, local production base, folk crafts).

As an obstacle to the development of the settlement network, the external factors inherent to the mountainous areas are: difficult living conditions at a distance to the centers with public services; deficit of agricultural land; low employment rate. The specificity of mountain territories is reflected in the "Development Strategy of the Ivano-Frankivsk Region 2020" (Ivano-Frankivsk Regional Administration, 2014), which focuses on the social needs of the population and the economic benefits of the territories. With regard to local settlement systems, this means subordination to local interests and those internal factors that promote the development of territorial communities. The local settlement systems themselves are becoming areas of a community-based administrative-territorial entities network formation.

Currently, within the framework of local settlement systems, the consolidation of territorial communities aimed at coherence of socio-economic and environmental measures, which will promote the sustainable development of systems, is being implemented. The association of villages with each other, as well as with urban settlements to solve common problems can be considered as an essential mechanism for the promotion of local systems to a qualitatively new level. The effect of such a mechanism can be seen on the example of Yaremche district in the developed strategy of the Yaremche-Vorokhta system development with the most important center of ski recreation.

On the example of the considered settlement systems it is possible to determine their future spatial development, having different forms of manifestation, defined as follows:

- Functional specialisation of each settlement system while preserving the leading role of the center of the system (Yaremche-Verkhovyna system: Mykulychyn, Tatariv, Polyanitsa).
- Territorial association of a group of settlements with the purpose of creating a specialised center-node (Verkhovyna, Kosiv system).
- Creation of a chain of settlements by integrating small settlements with a concentration of service functions in the center (Vyshkiv system).

Factors and principles of settlement systems formation, considered on the example of mountainous areas of Ukrainian Carpathians, can be applied to other regions of the Carpathian Mountains. These settlement systems are based on new criteria in the conditions of dynamic economic entities. The peculiarity of the considered systems is the active inclusion in the process of their development of recreational skiing, which is associated with the creation of a single natural-economic complex and at present is a critical condition for their functioning in the long term perspective.

Conclusions. Based on the above-mentioned material, it can be argued that local settlement systems are the main form of resettlement in the mountainous regions of the Carpathians. The principles of the formation of such systems on the basis of recreational skiing are considered only as a fragment of scientific knowledge on this problem, which allows a connection to be established between recreational skiing and settlement systems.

The placement of objects of recreational skiing in settlement systems is depicted in the design of schemes of local level. Within the spatial planning, the boundaries of settlement systems, the main and secondary axes of settlement systems development, as well as territories of different functional purposes are determined.

Thus, local settlement systems become a separate object of territorial planning at a lower level, where urgent problems are identified, priority to their solutions is given, and objects for investments are set.

In planning local settlement systems the opportunity is provided to make more informed decisions unlike the master plans that are currently being developed for settlements without considering them as elements of settlement systems and without taking into account systemic links, in particular, with objects of recreation.

Thus, local settlement systems as a multidisciplinary object of urban and spatial planning allow for a more in-depth study of the socio-economic, urban and natural basis of the settlement network at a lower level associated with the recreational skiing of the Carpathians in the framework of the overall strategy for the development of this macro-region.

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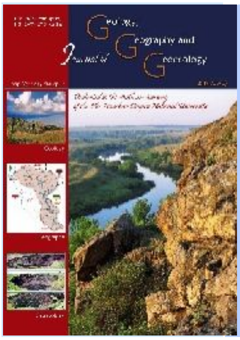

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Analyzing the parameters influencing the efficiency of undereground coal gasification

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Abstract. Relying upon the theory and practice of *Podzemgaz* stations operation, the paper has analyzed the basic factors working on the efficiency of underground coal gasification; moreover, it has estimated their function in the formation of gas loss from underground gas generator. The determined factors have been divided into initial factors and controllable ones according to their process characteristics and degree of their influence of gasification process itself.The data confirm the dependence of the increased pressure upon the increased heat output. Moreover, high static pressure within gas generator prevents from rock roof caving and reaction channel filling up with molten rock. It has been substantiated that almost all disturbing factors have negative effect on gas calorifity whereas parameters of blast rate increase and static pressure growth in a gas generator have the most positive effect among the controlling factors. Aspects concerning the increase in loss of the produced gas that may reduce economic efficiency and environmental safety of underground coal gasification have been considered as well.

Keywords: *filtration and crossflow processes, capacitive parameters, hydraulic fracturing, repression, relaxation, coal gasification*

Дослідження параметрів, що впливають на ефективність процесу підземної газифікації вугілля

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Анотація. В даній роботі на базі науково-практичного досвіду роботи станцій «Підземгаз» досліджено основні фактори, що впливають на ефективність процесу підземної газифікації вугілля, а також оцінюється їх роль у формуванні витоків газу з підземного газогенератора. Встановлені фактори структуровані по технологічним ознакам на вихідні та керовані та ступені їх впливу на процес газифікації. Наведені дані підтверджують залежність між підвищенням тиску і збільшенням теплотворення газу. Крім того, створення високого статичного тиску в газогенераторі перешкоджає обваленню його породної покрівлі і заповнення реакційного каналу розплавленою породою.Обґрунтовано, що практично всі обурюючі фактори негативно впливають на теплотворну здатність газу, а найбільш позитивний вплив з керуючих факторів надають параметри збільшення витрати дуття та підвищення статичного тиску в газовому генераторі. Також розглянуті аспекти збільшення відходів виробленого газу, що може знизити рентабельність та екологічну безпеку підземної газифікації вугілля.

Ключові слова: фільтрація та процеси в покрівлі, ємнісні параметри, гідророзрив, репресії, релаксація, газифікація вугілля.

Introduction. The necessity to make a technique of coal extraction, conversion, and use more ecologically feasible on the crucially new basis, while minimizing the environmental impact and reducing waste volume, is one of the topical problems to be solved by energy sector of Ukraine. Underground coal gasification (UCG) is the innovative solution to the problem. The process relies upon the transition of a mineral into a movable gas-condensate state within its occurrence by means of thermo-chemical and mass-exchange reactions. Gasification is fol-lowed by the loss of gas, being formed, into enclosing rocks which value is influenced by a number of factors. In this context, gas loss may achieve 30% affecting ecological compatibility and efficiency of UCG significantly. Thus, object of the paper is to study the parameters affecting the process of underground coal gasification as well as gas loss into roof rocks of underground gas generator.

Statement of basic material of the research. Relying upon domestic and the world practices, as well as scientific research (Korolev, 1962, Yefremochkin, 1960, Yudin, 1958, Saik, 2018), following basic factors, affecting the efficiency of underground coal gasification, can be singled out: 1) mining and geological environment of the deposit occurrence; 2) amount of water, involved into the gasification process; 3) mineral composition of coal; 4) characteristics of blast delivered to the gas generator; and 5) arrangement of wells. The factors may be divided into controllable (those which can be varied during UCG process), i.e. blast characteristics, and arrangement of wells; and initial factors (which cannot be varied), i.e. mineral composition, and coal seam thickness.

Coal seam thickness, its depth as well as tectonic disturbance of enclosing rocks are among the mining and geological conditions affecting UCG process. Increased seam thickness results in the decreased heat loss in the environment, decreased specific water inflow, and ultimately, in the increased gas heat as well as gasification process efficiency. However, specific gas output lowers due to the decreased seam mining as for its thickness. Thus, according to operation data of gas generators ##5, 5a-b, and 6 of *Yuzhno-Abinskaia* station of *Podzemgaz* (Nusinov, 1963), gas heat output, obtained within *VnutrenniIV* seam with 9 m thickness, is 1-1.5 MJ/m^3 higher to compare with *Vnutrenni VIII* seam with 2.2 m thickness. In this context, specific gas output is less by 1 m^3/kg and gasification efficiency of thicker seam is 10-15% higher.

Coal seam shallowness results in gas loss through overlying rocks; in turn, significant coal seam depth results in sharp efficiency decrease. Availability of faults, tectonic disturbances, and complicated seam hypsometry troubles the development of a reaction channel as well as control over a combustion source. Less than 100 m depth of a coal seam occurring within undisturbed rocks is optimum for its mining by means of UCG technique making gasification process more stable (Yefremochkin, 1960).

In the process of UCG, water balance is formed of natural coal humidity, inflows of water to a gas generator, water, containing in the blast, and water, being formed in the process of carbon, hydrogen, and methane combustion as well as *CO* conversion. Low water within the coal as well as nonavailability of water inflows may results in moisture lack which will decelerate gasification process; among other things that gives rise to the decreased *CO* formation during reduction reactions. Much water decelerates coal seam degassing, and reduces heat content of gas, being generated, due to its increased water ratio (Fig. 1). Hence, the amount of water, involved in UCG process, should be controlled strictly depending upon specific conditions.

The main procedures to control amount of water, participating in UCG process, are: preliminary dewatering of a deposit by means of drain wells; increased pressure of the blast to displace moisture from the gas generator; increased oxygen content within the blast; and increased air to be supplied.

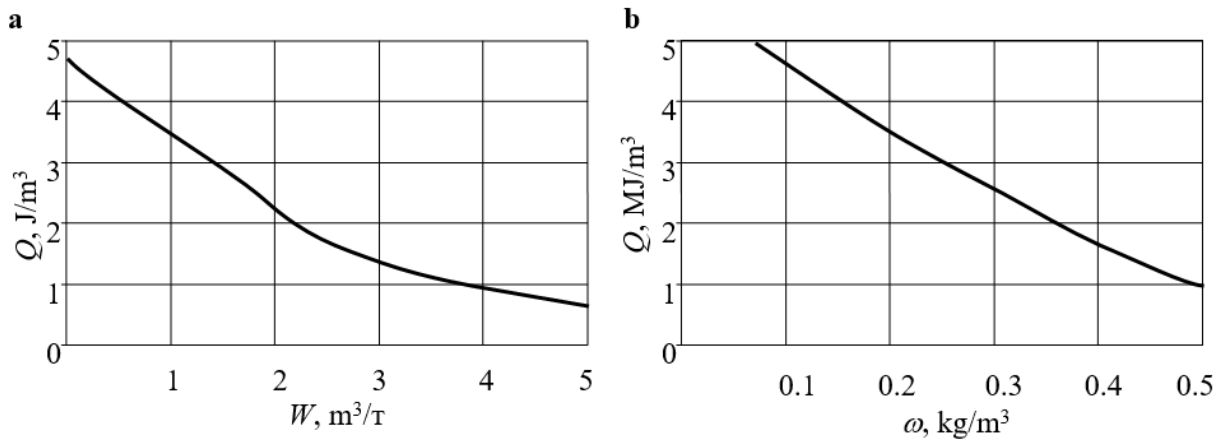

Fig. 1 Dependence of gas heat output (Q) upon:a – specific water inflow to the seam (W); and b – gas water content (ω)

Changes in characteristics of blast, delivered to the gas generator as well as chemical content of the blast, delivery rate, and delivery pressure are the important factors effecting gasification procedure (Arinenkov, 1960, Inkin, 2018). Analysis of the results of coal seams gasification shows that blast oxygenation increases temperature within combustion area; delocalizes it; and intensifies heat output of the gas, being generated. If oxygen content of the blast to be delivered is two times higher than atmospheric one, then the content of *CO* and H_2 experiences 1.5 to 2 times increase. Water vapour with 0.15-0.2 kg/m^3 content added to air blast (within the drained deposits) intensifies reduction reactions increasing CO, H_2, and CH_4 output. Combined use of oxygen and water vapour (i.e. vapour-oxygen blast) is more efficient. A Table demonstrates the influence of blast content on the heat output of the generated gases in the context of different UCG stations.

Experiments, concerning the effect of blast intensity on the gasification process were carried out within gas generator #1 of *Yuzhno-Abinskaia* station of *Podzemgaz* during its different operation periods. To begin with, blast consumption was increased from 1000 to 6500 m^3 per hour; then, it was decreased gradually from 6500 down to 1000 m ^{3} per hour. Fig. 2 explains changes in the content and gas heat output in terms of various consumption of blast delivered for gasification.

Table. Influence of the blast chemical composition on the gas heat output

Blast type	Station	Gas heat output, MJ/m^3
Air blast	*Lisichanskaia*	3.1
	Podmoskovnaia	3.6
	Yuzhno-Abinskaia	4.6
Oxygen blast	*Lisichanskaia*	5.3
	Podmoskovnaia	7.3
Vapour-air blast	*Yuzhno-Abinskaia*	6.3
Vapour-oxygen blast	*Podmoskovnaia*	6.8

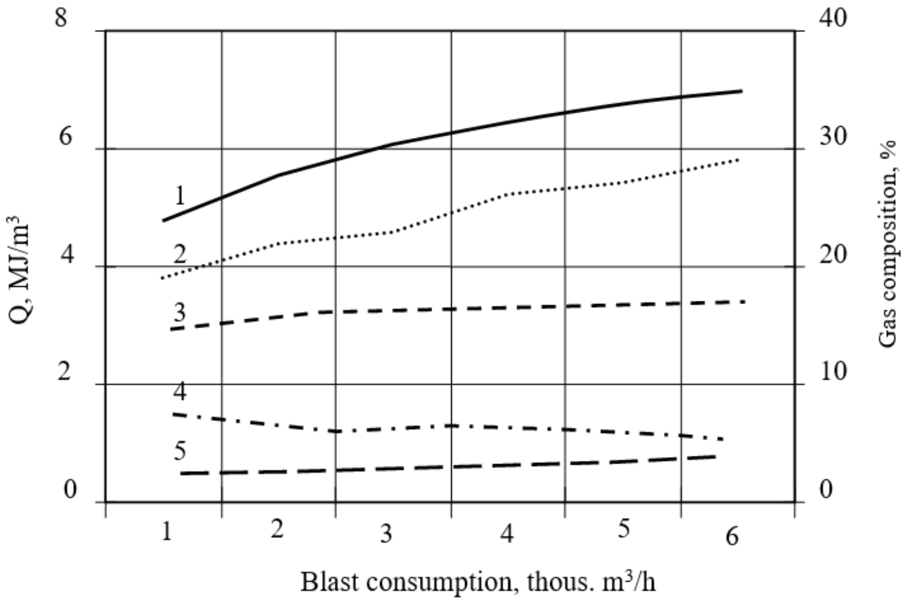

Fig. 2. Changes in gas heat output *Q* (1) and its composition CO(2), H_2(3), CO_2 (4), CH_4 (5) in terms of various blast types

The graph demonstrates that gas heat output increases depending upon the increase in the blast consumption. Moreover, the increase in heat value depends on carbon monoxide mainly. Carbon dioxide content within the gas reduces moderately while blast intensity increasing; at the same time, content of other components remains constant being more or less independent of the blast consumption.

Experiments have determined (Kulish, 1958) that in addition to the blast intensity, interrupted blast to a reaction channel is one of the factors intensifying heating value of gas as well as the efficiency of UCG station. Fig. 3 represents a graph of changes in gas composition in the context of Gorlovka *Podzemgaz* station. When gasification channel operated with the use of air blast (section A), H_2 + CH_4 content within the gas was 15-18% in the context of 4.8 MJ/m^3 average heating value. After blast was interrupted to the gasification channel, intensive increase in H_2 + CH_4 content started; the increase continued during the whole blastless period (section B). Then, when blast was restarted, composition of the gas, being generated, varied sharply. After 80 minutes it came up to the level when the channel operated with the use of air blast, i.e. H_2 + $CH_4 \approx$ 15-18 % (section C). During blastless period, the peak H_2 + CH_4 content was 58%, and heat output was up to 11 MJ/m^3.

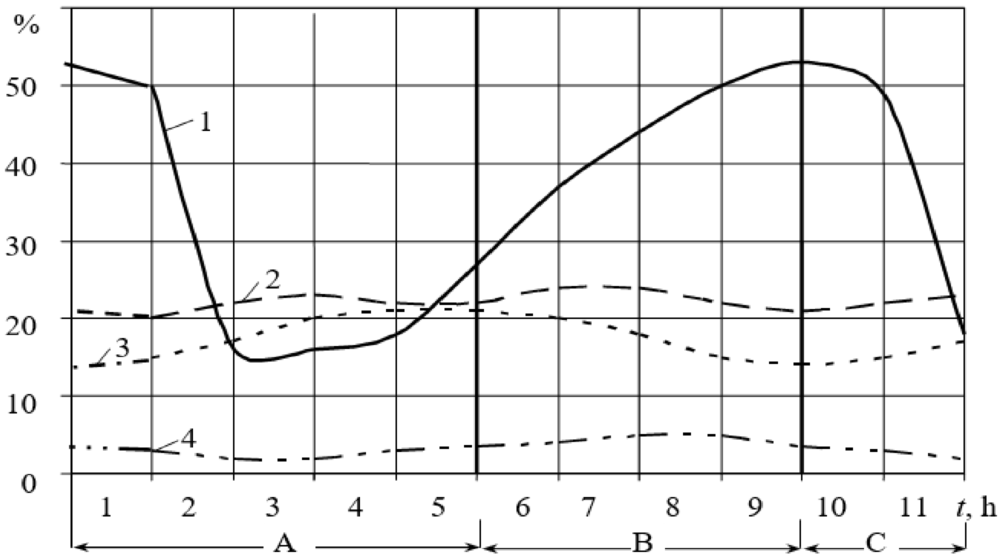

Fig. 3. Changes in the concentration of gas components (1 – H_2; 2 – CO_2; 3 – CO; 4 – CH_4) during blast and blastless periods of underground gas generator operation

Ash washing off coal surface, decreased aerodynamic drag factor, and increased coal loosening are the advantages of pulsating blast delivery. Use of the technique intensifies a process of gas release, and reduces the influence of negative factors arising with uniform blast.

Effect of static pressure within gas generator on gas heat output and loss value was analyzed at *Podmoskovnaia* station of *Podzemgaz* during 1954-1956 (Garkusha, 1964). During the period, static pressure varied significantly; averaged data can help estimate its change influence (Fig. 4). As it is seen in the graphs, increased pressure results in the increased heat output as well as in the increased gas loss. Average 10^4 Pa pressure increase results in 0.25 MJ/m^3 gas heat output increase and in 5% gas loss increase.

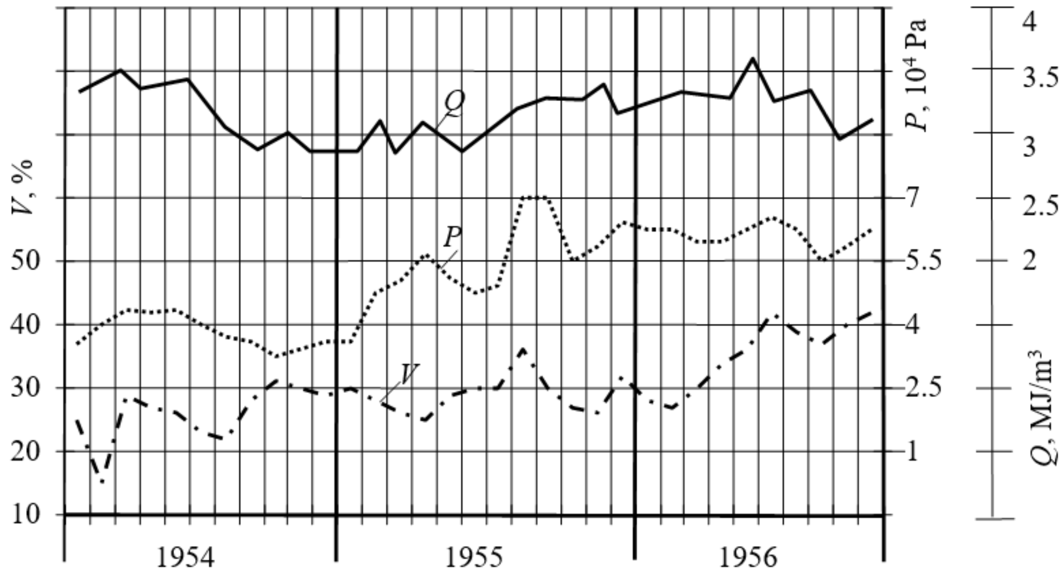

Fig. 4. Changes in static pressure (*P*), heat output (*Q*), and gas loss (*V*) in *Podmoskovnaia* station of *Podzemgaz*

Fig. 5 shows changes in gas humidity depending upon static pressure. Increase of static pressure results in certain forcing out of formation water owing to which moisture content of the gas reduces. The data confirm the dependence of the increased pressure upon the increased heat output. Moreover, high static pressure within gas generator prevents from rock roof caving and reaction channel filling up with molten rock.

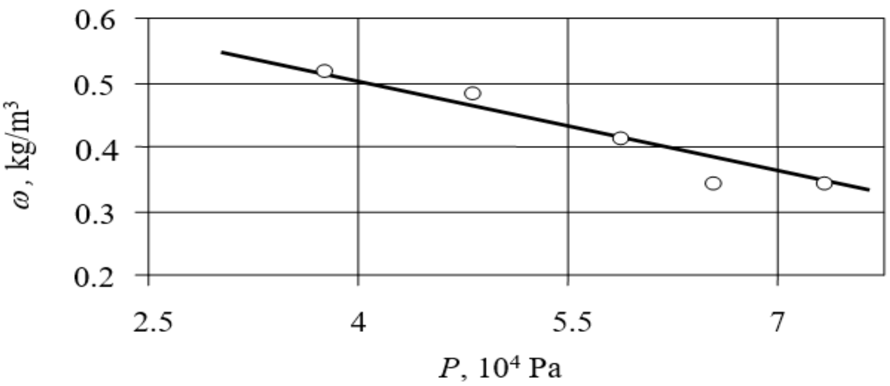

Fig. 5 Dependence of gas humidity (ω) upon static pressure (P)

Conclusions. Thestudies concerningthe factors, working upon the efficiency of underground coal gasification, have shown that perturbing factors are not equal to controlling ones in terms of their degree of influence. All the perturbing factors with the exception of a coal seam thickness have an adverse effect on gas heating power; in turn, blast characteristics are the most favourable ones among controlling factors. Hence, increased blast consumption and increased static pressure within a gas generator are the most active controllable factors working on the efficiency of UCG process. Conversely, that results in the increased gas loss which may decrease both profitability and environmental safety of UCG.

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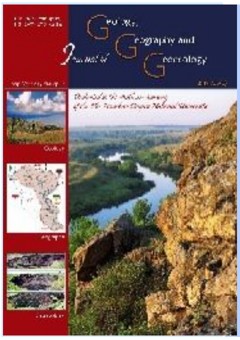

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The main problems of healthcare and wellness tourism in Ukraine

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Abstract. The data of the conducted research testify to the high potential of Ukraine, taking into account factors such as favourable climate, location near two seas and rich natural resources for healthcare and wellness tourism. Significant weaknesses have been identified, which consist of an outdated infrastructure of healthcare and wellness enterprises and the narrow range of services provided by them. Only 67% of the total number of establishments of the sanatorium and resort complex have service departments inside, but even if they are available, most of the health-improvement facilities according to the requirements of the National Standard for Accommodation do not even correspond to category 1. In the course of the conducted research, methods of statistical analysis were applied to study the dynamics of the number of sanatoria and health facilities in Ukraine and the number of tourists. Methods for diagnosing the state of development and modeling (including SWOT analysis, cluster approach) were used to study the functioning of tourist territories of different taxonomic ranks. It was found on the basis of study that although Ukraine has all the resources for the development of healthcare tourism, it is still a depressed industry owing to numerous problems. The materials of this research can become a practical basis for the development of this kind of tourism. The main problems of development of tourist infrastructure of healthcare tourism are described. The directions of its development are proposed: construction of new hotels, recreation centers, shelters, hotels, camping sites, etc. and reconstruction of available accommodation facilities. It was found that a similar situation is observed in the places of public catering (their significant insufficiency negatively affects the development of this sphere of tourism). It is proposed to create an innovative cluster of health-improving type on mono-territories, which will allow the best possible social and economic development projects to be designed and implemented, as well as helping to effectively build and implement a strategy for long-term development of the territory, which has favourable conditions for sanatorium and resort treatment.

Key words: *healthcare and wellness tourism, sanatorium and resort business, spa business, sanatoria-resort cluster.*

Головні проблеми розвитку лікувально-оздоровчого туризму в Україні

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Анотація. Дані проведеного дослідження свідчать про високий потенціал України, з огляду на такі чинники як сприятливий клімат, розташування поблизу двох морів, багаті природні ресурси, які доцільно максимально використовувати в лікувально-оздоровчому напрямку туризму. Виявлено значні слабкі сторони, які полягають в застарілій інфраструктурі лікувально-оздоровчих підприємств і вузький асортимент надаваних ними послуг. Із загальної кількості закладів санаторно-курортного комплексу підрозділи сфери сервісу мають тільки 67 % установ, проте навіть за наявності таких, більшість оздоровчих закладів згідно вимог Національного стандарту до засобів розміщування не відповідають навіть категорії 1. В ході проведеного дослідження для вивчення динаміки кількості санаторно-оздоровчих закладів в Україні, кількості рекреантів були застосовані методи статистичного аналізу. Для вивчення стану функціонування туристичних територій різних таксономічних рангів використовуються методи діагностування стану їх розвитку та моделювання (у тому числі SWOT-аналіз, кластерний підхід). Виявлено на підставі дослідження, що хоч Україна має всі ресурси для розвитку оздоровчого туризму, це депресивна галузь через наявність численних проблем. Матеріали дослідження можуть стати практичною основою для розвитку такого виду туризму. Охарактеризовано основні проблеми розвитку туристичної інфраструктури оздоровчого туризму. Запропоновано напрями її розвитку: будівництво нових готелів, баз відпочинку, притулків, готелів, створення кемпінгів і т.д. і реконструкція наявних об'єктів розміщення. Виявлено, що аналогічна ситуація спостерігається і в плані місць громадського харчування (суттєва їх недостатність негативно впливає на розвиток даної сфери туристичної діяльності). Запропоновано створення інноваційного кластера лікувально-оздоровчого типу на монотериторіях, що дозволить найкращим чином спроектувати можливості соціально-економічного розвитку, а також ефективно вибудувати і реалізувати стратегію довгострокового розвитку території, яка має сприятливі умови для санаторно-курортного лікування.

Ключові слова: *оздоровчий туризм, санаторно-курортний бізнес, СПА-бізнес, кластер лікувально-оздоровчого типу.*

Introduction. Healthcare and wellness tourism tourism is one of the types of tourist and recreational activities, which involves traveling to the regions with the most favourable natural conditions , including climate for health, , for the prevention, treatment or rehabilitation of disease. It is one of the most stable types of tourist markets and priority areas in Ukraine. However, itis greatly in need of support and coordinated development. Available and potential reserves of treatment resources, taking into account of their qualitative and quantitative characteristics, should now become the stimulus for public practice in human health restoration, extending the active period of life and introducing of a healthy lifestyle, all of which determines the relevance and subject matter of this article.

Ukraine has a fortunate combination of diverse and rich natural resources, thatcan be used to preserve and improve the health of the population, extending life expectancy: a favourable climate and range of ecological zones , forest, forest-steppe and steppe, mountainous and coastal areas, a unique microclimate of salt mines, a wide range of natural mineral waters, therapeutic mud, ozokerite, etc.

Material and methods of research: The methods of statistical analysis were used in order to study the dynamics of the number of sanatoria and health institutions in Ukraine and the number of tourists. To study the functioning of tourist territories of different taxonomic ranks, methods of diagnosing the state of their development and modeling are used. Methods of diagnosing the state of the tourist and recreational system are systematic procedures for describing the system and its components with the use of qualitative and quantitative parameters.

A clear reflection of the status of tourist systems are models (including clusters), which conditionally represent the image of the object which is in a certain accordance with the system.

In recent years, for the study of many phenomena of social life, the SWOT analysis (in the translation of the word – strength, weakness, opportunities, threats) has been applied more widely, which involves studying the "strategy of behaviour" of the objects under the influence of four groups of factors (the advantages of the territory, favourable factors of the environment, deficiencies of the territory, counteraction to the external environment). The practical result of the SWOT-analysis should be the corresponding table showing the strategic directions of the development of tourist objects or regions (Fig. 1).

The continuation of this method is the so-called TOWS-analysis, which involves forecasting of changes in these objects due to changes in the environment (Table 1). Thus the focus is on the construction of four groups of different strategies , each of which uses one of the pair combinations (Kolodii, Sprynskyi, 2005).

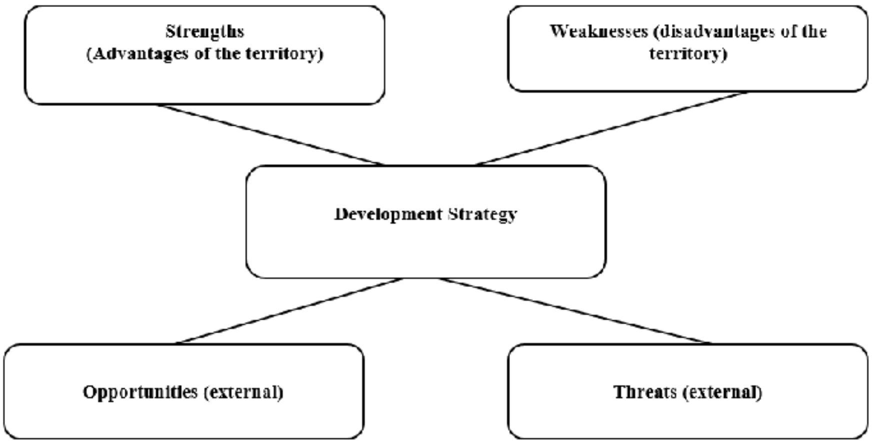

Fig. 1. Components of the SWOT analysis of the territory

Such methods can be supplemented by other expert ones, but the main role in forecasting the development of tourist areas is played by factorial methods. They include methods of analysis of dynamics, spatial interaction, taxonomic grouping (classification), optimization of development (Lebedieva, 2011).

Table 1. The matrix of TOWS-form

	O (Opportunities)	**T (Threats)**
S (Strengths)	**SO** (success strategy) ***«Maxi-Maxi» strategies*** strategies of using strengths to use the opportunities provided	**ST** (conservation strategy) ***«Maxi-Mini» strategies*** strategies of using strengths to minimize threats
W (Weaknesses)	**WO** (competition strategy) ***«Mini –Maxi»strategies*** strategies to minimize weaknesses through the use of opportunities provided	**WT** (defense strategy) ***«Mini- Mini»strategies*** strategies for minimizing weaknesses and threats

Results and their analysi. In our time, health tourism is one of the main components of the tourism industry, especially for inhabitants of economically developed countries, where influential factors are the consequences of transport development, its active promotion, pollution of the environment due to industrial development, etc. A healthy lifestyle means that many people are looking for health and relaxation in other, environmentally friendly regions. Health tourism is based on the use of natural resources: mineral water, therapeutic mud and climatic conditions, which in combination with each other positively affect the treatment of various diseases.

The development of healthcare and wellness tourism is closely linked to the state of the sanatorium and spa industry, and Ukraine’s current conditions it faces certain difficulties. The number of spa complexes and resorts is reduced, there is lack of funding, physical deterioration of medical equipment, etc. But despite this, Ukraine has rich recreational tourism potential and important prerequisites for the creation of highly developed tourist facilities.

The political instability in the country and deep financial and economic crisis have led to an increase in the cost of services with poor quality of service, which is the reason for the decline in demand and the reduction in the occupancy of sanatoriums, which is today at about 40% capacity.

Another problem that the research suggests is that there is now a real threat to the national security of Ukraine due to low birth rates, high morbidity and mortality.

The most important criteria that characterize the health of the population are:
1) the frequency of newly established cases of disease per year;
2) prevalence of the disease (ie, all cases of the disease detected during the year, including the first detected and chronic cases that had existed before).

According to the State Statistics Committee, the general level of incidence per 100 thousand of the population in the period 1995-2017 in Ukraine has increased by 58.4%, and in 2017 there were 67,998 episodes of morbidity compared to 42,947 cases in 1995. The number of registered cases for the first time remains practically the same (Table 2). By comparison - the level of morbidity in European countries is approximately 40,000 cases per 100 thousand of population (The Law of Ukraine "On Resorts", 2000).

Table 2. The morbidity dynamics of the population of Ukraine

Years	Number of cases of disease per 100 thousand of population, persons	The number of first-time cases of disease, persons
1995	42,937	32,547
2000	59,439	33,471
2005	81,916	32,912
2010	78,148	33,080
2015	68,558	26,881
2017	67,998	26,789

Given the above-mentioned problems, the organization of effective rest, health and recreation, prevention and reduction of morbidity and disability, as well as the health promotion of the population of all age groups are of particular importance during a period of challenging socio-economic and environ-mental conditions (Lebedieva, 2011).

The climatic resorts of the Southern coast of Crimea, the balneological resorts of the Pre-Carpathian and Transcarpathian regions, Podillya, Poltava, the mud-resorts of Crimea and Odessa region are well-known since ancient times. The first institutions that used mineral water for treatment began func-tioning in Shklo (1576), Saky (1799), Truskavets (1827), Odessa (1829), Berezovske (1862), Morshyn (1877); the healing properties of the mud – on the shores of the Liman Kuyalnyk (1833), and near Gola Prystan' (1895).

In recent decades, there has been a tendency towards a decrease in the number of sanatorium and wellness establishments (see Table 3), which is due to a number of problems that exist in the country (socio-economic, military operations in the east, occupation of the territory of the Autonomous Republic of Crimea, etc.)

By 2017, the number of health-improvement institutions of all types had decreased by almost 2 times compared with 2010. This is especially true for children's recreation camps (decreased from 17.3 thousand institutions to 9.6 thousand), sanatoria and boarding houses with treatment (decreased from 510 institutions in 2010 to 290 in 2017), as well as sanatoria-preventive clinics (234 establishments in 2010 compared to 63 in 2017). This is due to the fact that a huge number of them was concentrated in the Crimea. Ukraine has lost these health facilities because the occupation of this territory.

Table 3. Sanatorium and health resorts

Years	Sanatoria and boarding houses with treatment		Sanatoria-preventive clinics		Holiday homes and pensions		Bases and other recreation facilities		Children's health camps	
	Total	Number of beds, ths	Total	Number of beds, ths	Total	Number of beds, ths	Total	Number of beds, ths	Total	Number of beds, ths
2010	510	141	234	19	290	60	1920	217	17342	196
2011	508	141	224	19	280	59	1947	216	17703	194
2012	484	133	185	18	286	60	1925	208	17744	188
2013	477	132	165	15	271	57	1916	202	18549	191
2014	320	79	118	17	90	17	1400	157	13977	126
2015	309	78	79	12	76	15	1399	165	9743	113
2016	291	70	63	10	73	14	1295	146	9669	112
2017	290	70	63	10	72	14	1295	146	2968	111

As Figure 2 shows, over the past 5 years, the number of health resort users has also significantly decreased. This fact can be explained by an increase in prices for services rendered in health facilities.

During the years of independence, the sana-to-rium and resort sector in Ukraine has practically re-mained without state subsidies. The lack of budget financing was a consequence of a reduction in a number of state programmes (sanatorium and resort treatment of patients with tuberculosis, traumatic diseases of the spinal cord, cardiac patients, etc.).

A significant number of health resorts are converted medical facilities and have gained the status of recreational facilities with a low level of service (The concept of the development of the sanatorium and resort industry, 2003). The general problems of healthcare and wellness tourism of Ukraine are due to:
uncoordinated regulatory policy;

- non-systematic use of natural therapeutic resources;
- imperfect infrastructure;
- high prices for fuel and energy resources;
- low quality of water supply.

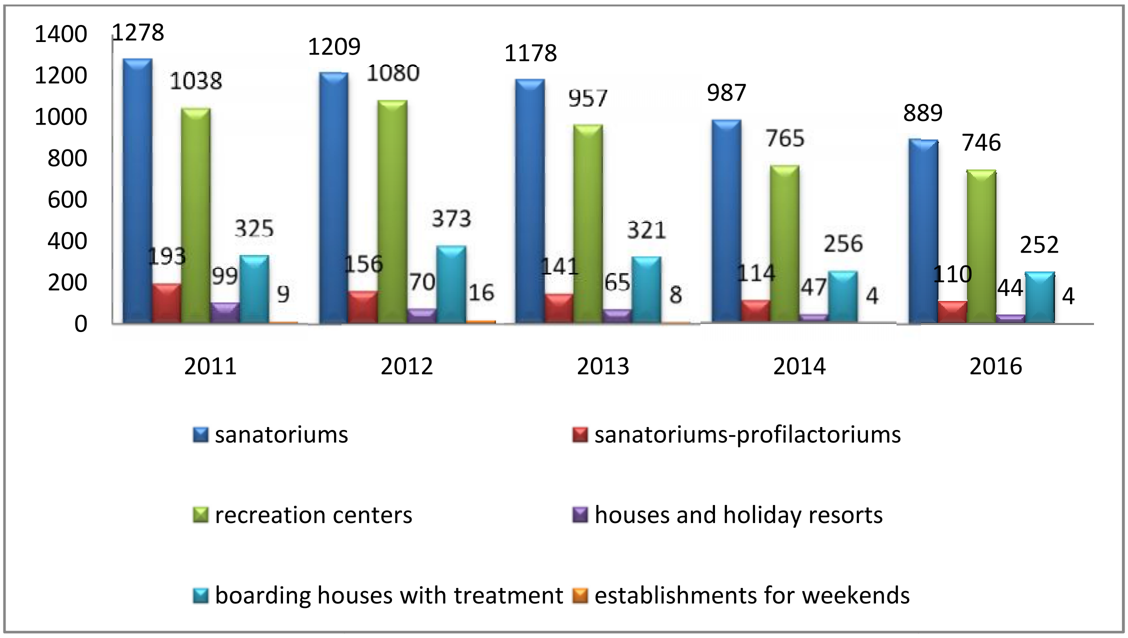

Fig. 2. Number of persons who have been to establishments within the sanatorium and resort complex, thousands of people

The sanatorium-resort sector is regulated by the Law of Ukraine "About Resorts", the current regulatory framework which regulates its functioning, the economical and rational use of natural therapeutic resources and their protection, declare that of sanatorium and health treatment should be accessible for citizens of all age groups, first of all, for the disabled , veterans of war and labour, combatants, citizens affected by the Chernobyl accident, TB patients, children and women of reproductive age (Zapototskyi, 2013). However, the imperfection of the system of legislative regulation is a significant obstacle to the year-round operation of the sanatorium and resort complex: in budgets of all levels, donations in the health system are neither foreseen nor equated to industrial enterprises after tax payment. Such conditions lead to a rise in the cost of sanatorium and resort services, reduce the possibility of loading health establishments, and, therefore, cause a number of socio-economic losses (Zapototskyi, 2013).

The development of healthcare and wellness tourism is directly related to the rational use of natural therapeutic resources in the territories dedicated to health-improvment. However, a significant number of health-improving institutions consume deposits of natural therapeutic resources with unconfirmed and invaluable reserves. Most of the exploited mineral water wells are technically and technologically obsolete and are usually used for industrial bottling in plastic containers. In this case, packaged mineral water is not used in accordance with medical zoning in other health facilities and in hospitals. The State inventories of natural medicinal resources and natural territories of resorts was created in Ukraine in order to compare the effectiveness of the recreational and non-recreational use of the resorts, the medical-biological assessment of the quality of natural therapeutic resources, the ecological and economic assessment of the natural areas of the resorts and the formation of the market for natural therapeutic resources and the introduction of a system of paid nature use.

The state inventory of natural areas of resorts is an effective instrument for monitoring, rational current and future use of natural areas of resorts in accordance with approved urban planning documentation for sanatorium treatment, medical rehabilitation, tourism and recreation development; ensuring effective collection, processing, preservation and analysis of information on the state of the environment and natural therapeutic and recreational resources in the territories of the resorts and forecasting their changes under the influence of economic activity; effective environmental protection measures and the development of scientifically substantiated recommendations on the use of natural ar-
eas of resorts.

Establishment of priority directions of the use of natural medical resources, improvement of the cultural-historical heritage, and protection and enrichment of the natural environment require the balance between interdisciplinary interests regarding the placement of resort, residential and social considerations, engineering, transport, communal and other objects. Thus, the development of the infrastructure of the territories of resorts and health-improvement areas requires the solution of complex territorial problems . At the same time, industrial zones pose a real threat to the deposits of mineral waters, mud and other natural medical resources. Intensification of economic activity, proximity of trunk roads with the low level of service, high prices, and imperfect infrastructure undermine the reputation of health facilities.

The development of healthcare and wellness tourism depends to a large extent on prices for fuel and energy resources, since they directly affect the cost of permits. Thus, the intensification of the introduction of energy-saving technologies, reproducible and non-traditional energy sources, which is an effective instrument for maintaining a sustainable ecological situation and the subject of state policy, promotes the minimization of the energy dependence of health establishments.

Sustainable development of healthcare and wellness tourism is impossible without modernization of water management, water treatment and sewage facilities; exploration and mobilization of underground water for drinking water supply and rational use of available sources. At present, the state priority is the construction of closed water supply systems for health facilities, regardless of their ownership and subordination, as part of the strategy of promoting non-waste technologies (Zapototskyi, 2013). It is worth emphasizing the diverse subordination of health-improving institutions. Sanatoria, boarding houses, houses and recreation facilities operate in different departments: professional trades union systems, the Ministry of Health, the Ministry of Internal Affairs, the Ministry of Transport, the State Department of Affairs, the Ministry of Industrial Policy, Fuel and Energy, etc. There are also institutions that are on the balance of large enterprises and associations. However, studies have shown that the crisis of the sanatorium and resort complex, is largely due to the lack of funds for the maintenance of health resorts in departments, on whose balance sheets they are fixed (Zaporoshchenko, 2017).

In addition to these problems, the development of healthcare and wellness tourism has the characteristic features of a crisis situation: the lack of effective economic mechanisms of functioning with a low level of service; the practical absence of internal and external investments at a high level of depreciation of fixed assets; unsystematic development of health facilities with ineffective managerial and marketing strategies, practices, methods and methods at macro, meso and micro levels.

Researchers emphasize that the strategies of development of resorts of state and local importance should take into account the introduction of an efficient system of financing the sanatorium and resort industry and the creation of a system for encouraging of investments in modernization and construction of sanatorium and resort industries, creating affordable health products, adherence to state standard treatment methods and medical rehabilitation at resorts, and coordination of activities of sanatorium and health resorts, regardless of the form of ownership and subordination.

Application. Analysis of the development of the strengths and weaknesses of the state of healthcare and wellness tourism in Ukraine is presented in Table 4.

The data presented in Table 4 shows the high potential of Ukraine, taking into account factors such as favourable climate, location near two seas, rich natural resources that are expedient to use as much as possible in the health and wellness tourism sector. There are significant weaknesses that lie in the outdated infrastructure of the healthcare facilities and the narrow range of services provided by them. Only 67% of the total number of facilities in the sanatorium and resort complex have service sector units, but even if they are available, most health-improving facilities do not even correspond to category 1 in accordance with the requirements of the National Standard.

At the same time, a holiday home, a pension, a health facility of 1-2 days of stay does not have any service area. It is necessary to emphasize separately the continuous non-compliance with the general requirements for taking into account the needs of the disabled and other low mobile groups of the population.

Opportunities are represented by a tendency towards investing public funds in the development of health-improving tourism and its infrastructure, in connection with the creation of clusters in the country, which will lead to the formation of a specific mono specialization in order to expand the interconnections within the recreational and tourist system, which imposes a significant imprint on trade, free movement of capital, human and information resources.

Despite the rapid development of information technology over the last decade, giving great possibilities for operative information exchange between companies, the territorial feature of the cluster does not lose its relevance today, as the special significance in the cluster association has regular informal connections, which are possible only in conditions of territorial proximity.

Table 4. SWOT-analysis of the state of healthcare and wellness tourism in Ukraine

Strengths	**Weaknesses**
- favourable climatic conditions of most of Ukraine, which can be widely used for climatology treatment of recreation; - geographic location, the country's exit to two seas - the Black and Azov, contributes to the development of resort and beach recreation in the recreational programs; - the presence of several natural deposits of medicinal mud, many deposits of mineral waters of different chemical composition; - the presence of such unique objects as the Carpathian Biosphere Reserve, the nature reserves "Synevir", "Medobory", "Dniester Canyon", etc., attracting visitors to tourists who are staying in health institutions; - border location of many health and recreation centers, which contributes to the development of inbound health and wellness tourism (Zakarpattia region, Odessa region); - availability of developed logistics transport corridors and rather well-developed port infrastructure; - existence of infrastructure for supporting small and medium enterprises	-healthcare and wellness tourism activity has a pronounced seasonality; - outdated material and technical base of many medical and recreational enterprises of the country; - inconsistency of the price and quality of providing health-improving tourist services; - insufficient use in the recreation of available natural therapeutic resources in the country; - a narrow range of proposed healthcare and treatment services by enterprises; - a narrow range of additional leisure services at healthcare and wellness enterprises; - insufficient promotion and branding of the regions of Ukraine as favourable for medical and health tourism; - absence of a unified policy of hospitality in the field of providing wellness and healthcare services; - high cost of transport services; - the absence of developed complexes of road infrastructure.

Opportunities	**Threats**
- attraction of state investments in the development of healthcare and wellness tourism in the country; - the possibility of forming interregional health tourism projects; - the possibility of forming time tourist and recreational centers at the expense of industrial clusters	- low level of development of specialized infrastructure and service of healthcare and wellness sphere of tourism, including hotels, public catering establishments, passenger transport; - unsatisfactory condition of tourist facilities, which are used in leisure activities as part of recreational rest of tourists; - the natural and climatic characteristics of individual regions (the Carpathian region, the Black Sea and the Sea of Azov) dictate the seasonal component and the unevenness of the provision of certain types of therapeutic and health services

A characteristic feature of a recreation-tourist cluster with healthcare and wellness mono specialization is not only the complementarity of the enterprises that belong to it but also the impossibility of their functioning outside the recreational and tourist sphere. Since territorial recreational systems include regional systems and functional networks (separate sectors of the recreational economy for their particular placement), the establishment of a stable network of horizontal links among its elements is the basis for the formation of specialized objects of space - cluster formations on the mono territories of tourist and recreational type.

Clusters can be located at the territory of one or several regions, and represent a special monospace – a special type of territory.

We note that in most cases special-type territories become associated into mono-specialized clusters, a cluster being considered by the authors as a certain group of interrelated companies, specialized suppliers of services, firms in the corresponding branches, infrastructure, research institutions, universities and other organizations (which are complementary and enhance the competitive advantages of each other and the cluster in general), which is concentrated in a territory characterized by a pronounced monospecialization. At the same time, in subsequent years, clusters become not only spontaneously organized groups of enterprises and organizations, but also a purposeful and quite effective instrument of state economic policy.

In particular, this form of organization in a number of countries has been used as the main instrument of the new economic policy (UK, PRC, Finland, USA, etc.), and in some cases also in the form of an anti-crisis strategy (Canada).

Formation of cluster recreational and tourist formations should be based on the objective competitive advantages of a mono-tier, taking into account their possible changes in the future, which undoubtedly requires not only the availability of natural prerequisites for the development of recreation and tourism, but also significant efforts in the formation of a favourable infrastructure (see Fig. 3).

The influx of tourists requires the presence of tourist infrastructure: the construction of new hotels, recreation centers, shelters, hotels, camping, etc. and reconstruction of available accommodation facilities. A similar situation is observed in terms of places of catering.

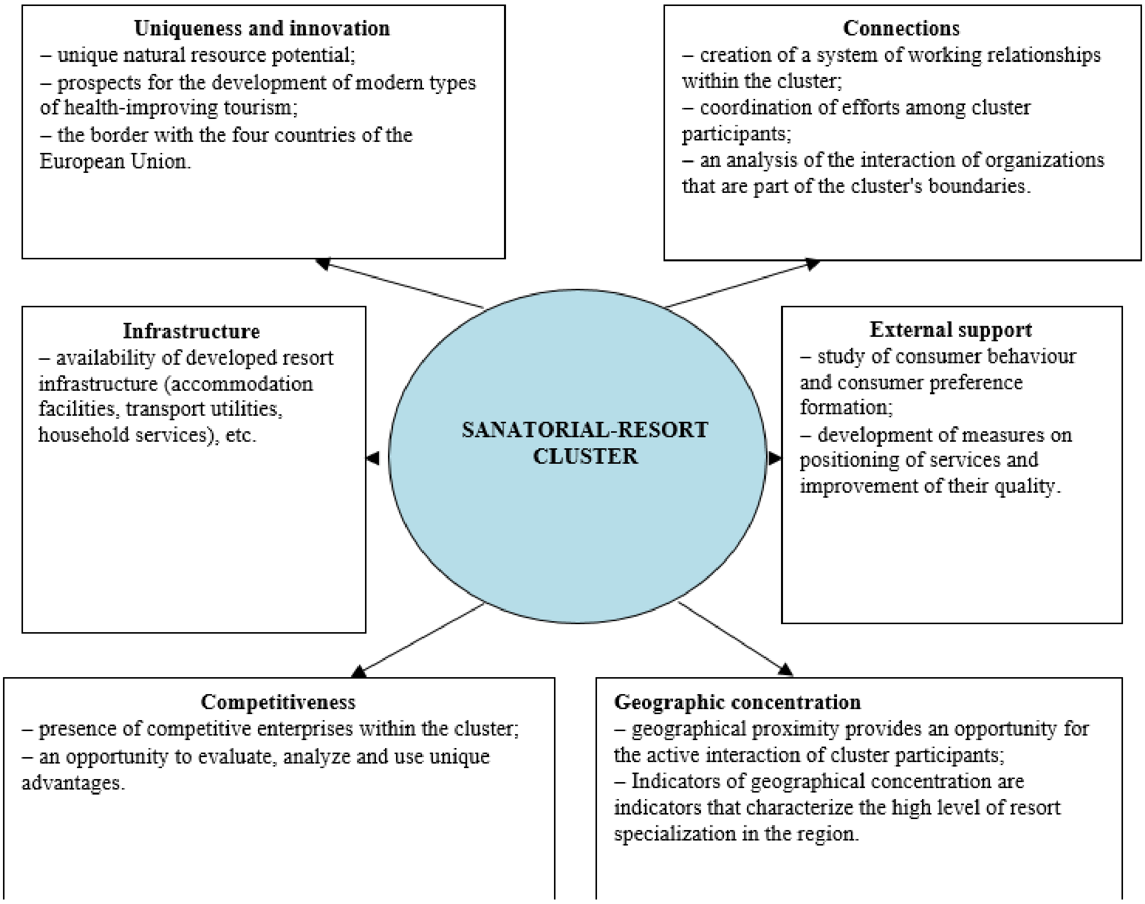

Fig. 3. The main features and characteristics of the business environment of the sanatorial-resort cluster

Creation of an innovative cluster of health-improving type on mono-territories will provide the best way to design opportunities for socio-economic development, as well as to effectively build and implement a strategy for long-term development of this territory.

The center of the healthcare and wellness cluster may be several powerful institutions of the sanatorium and resort area, engaged in the production and promotion of tourist products of the region, which help each other, that is, position the cluster. The territorial situation may range from one to two major tourist monospecialized points (or centers) within villages, cities / hubs, districts, zones within the region / country and even several neighboring countries (cross-border clusters), which often leads to a synergistic effect.

Clusters by their existence prove the effectiveness of public-private partnership in achieving the goal of sustainable tourism development within a region, providing quality tourism services, stimulating demand and maintaining its proper level, providing local people with jobs.

Conclusions. The current market situation reveals the weak and strong sides of the Ukrainian resorts, formed in the above-mentioned historical conditions. For example, the strengths or **competitive advantages** are: the availability of treatment for a wide range of people; medical specialization and purpose of sanatorium-resort establishments, powerful scientific potential; **weaknesses** are: the weakened factor of "historical uniqueness" in the brands of some domestic resorts compared with foreign ones; in fact, the absence of well-known domestic brands in the sanatorium and resort industry, with the exception of several resort associations; low level of service and diversification of services; low profitability due to "hereditary" low prices.

In order to eliminate the mentioned negative factors of development of the sanatorium and resort complex it is expedient to:

1) implement social policy in order to further increase the level and quality of life of the population;

2) improve the efficiency of the general state and regional regulation of the sanatorium and resort sphere;

3) develop and implement a complex of measures aimed at attracting investments for the development of the infrastructure of the sanatorium and resort complex;

4) improve the system of publicising the possibilities of the healthcare and wellness industry of the country as a whole, to position Ukraine on the

world market of healthcare and wellness services as a major region of treatment and rehabilitation;

5) develop the information and advertising and marketing activities of sanatorium and resort establishments; balance the price policy and quality of the basic and additional healthcare and wellness services, introduce a system of discounts;

6) improve the organization of the activities of sanatorium and spa establishments, aimed at reducing the cost of their maintenance and reducing the cost of travel vouchers;

7) pay more attention to the development and implementation of innovative measures for the offer of individualization at the resort and the formation of new domestic brands in the market of sanatorium and resort services of Ukraine by the enterprises of the healthcare and wellness industry;

8) staffing of the healthcare and wellness establishments with qualified specialists.

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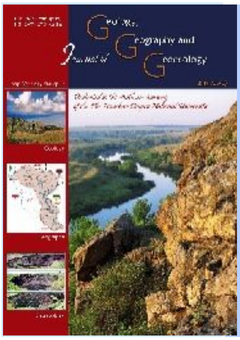

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On the modern conception of environment

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Abstract. Currently a large number of, geographers and representatives of related sciences claim to have created integrated environmental concepts . This applies, in particular, to the concepts of "environmental science", "sociogeosystems", "anthropogenic landscape", "eco-geosophia", etc. All of them confirm the importance of solving the global environmental problem, and the need to unite scholars in all specialties. There is a significant revival of interest in the integral essence of geography, especially among anthropogeographers. This testifies to the fundamental unity of geographical science without its distinct division into natural and social geography, which divides the discipline up into a plethora of specific objects and subjects. Anthropogeographers have come to understand that the earth's space was initially organized by Nature itself. Mankind from the Neolithic Age has transformed his use of nature into the noosphere. If before the Neolithic revolution there still existed natural landscapes on the surface of the planet , then the Neolithic populations of *Homo sapiens* started to actively change the environments they inhabited. Approximately then, the search for ways to justify such, often destructive, intervention began. Such a change in the landscape was brought about by man, which encouraged scientists unwittingly to develop an "intentional paradigm", according to which the methodology of each science tries to take into account the role of man not only as a component of nature, but as its researcher. Even Strabo having realized the many-sidedness of human existence on our planet, already in ancient times, considered himself "not a geographer, not a historian, but a philosopher." Hettner, with his idea of "embedding" into the earth's space of all things, considered the object of studying geography this very earthly space with objects and phenomena that filled it and interacted with each other. According to Hettner, the connections between them have a landscape causal nature. To such systems of geobjects, Hettner also related human society. The idea of "through" was found in the works of our contemporary physicist and geographer Aleksey Reteyum, who discovered integral (socio-natural) spatial entities on the surface of the planet ("choriones" and "sphragids"), once again proving the "right to exist" of the noosphere suggested by Volodymyr Vernadsky. At present, it is geographers who must create an adequate concept of the environment, which is not yet developed in completed form. Its final design will require the rejection of the mechanistic perception of the world, divided into objects and subjects of research. It is geographers who should identify in time and space such integrated environmental systems (socio-natural systems, whose subsystems can be natural landscape systems and sociogeosystems), which are shaped as a result of the joint development of nature and society. Prospects for the productive development of environmental science are related to the concept of noosphere ecosystems.

Keywords: environment, noosphere, anthropogenic landscape, intentional paradigm, socio-natural systems.

Про сучасну концепцію довкілля

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Анотація. Численні сучасні концепції довкілля часто претендують на інтегральність. Це стосується, зокрема, концепцій «середовищезнавства», «соціогеосистем», «антропогенного ландшафту», «екогеософії» тощо. Знаковим є відродження інтересу до інтегральної сутності географії саме серед антропогеографів, що свідчить про принципову єдність географічної науки. Антропогеографи поступово доходять розуміння того, що земний простір від початку був організований самою Природою. Людство ще з неоліту здійснює на Землі ноосферне природокористування. Якщо до неолітичної революції на денній поверхні планети ще існували природні ландшафти, то з неоліту популяція Homo sapiens починає їх активно змінювати. Приблизно тоді ж почались пошуки способів виправдання такого, часто руйнівного, втручання. Така змінена до непізнаваності людиною ландшафтна оболонка спонукала науковців розробляти «інтенціональну парадигму», за якою методологія кожної науки намагається врахувати роль людини не лише як складової природи, але як її дослідника. Сьогодні саме географам належить створити адекватну дійсності концепція довкілля, яка в завершеному вигляді поки що не розроблена. Її остаточне оформлення вимагатиме відмови від механістичного сприйняття навколишнього світу, поділеного на об'єкти і предмети дослідження. Саме географам належить позначити в часі й у просторі такі інтегративні системи навколишнього середовища (соціоприродні системи, підсистемами яких можуть бути природні ландшафтні системи у різному ступені змінені людиною), які утворені в результаті спільного розвитку природи і суспільства. Перспективи продуктивного розвитку науки про довкілля (довкіллєзнавства) пов'язані з концепцією ноосферних екосистем.

Ключові слова: довкілля, ноосфера, антропогенний ландшафт, інтенціональна парадигма, соціоприродні системи.

Introduction. The article is the continuation of the discussion about the concept of the environment, which once again (after V. Nikolayev (Nikolayev, 2006), V. Nekos (Nekos, Nekos, Safranov, 2011), M. Holubets (Holubets, 2015), O. Kovalyov (Kovalyov, 2014), H. Denysyk (Denysyk, 2001) and others) was carried on in the article by O. Topchiev, D. Malchykova, I. Pylypenko and V. Yavorska (Topchiev, Malchykova, Pylypenko, Yavorska, 2017).

The very fact that the article was published in 'Ukrainian Geographic Journal' in the section 'Call for Discussion', testifies to the extraordinary urgency of this problem. It is noteworthy that this section in UGJ reminds one of an old trap, which the editorial board regularly walks into, however, it always appears on its way. Indeed, there have been more than 10-15 articles dealing with the problem in this section since the mid-1990s (V. Pashchenko, I. Chervaniov, O. Kovalyov, O. Topchiev, M. Holubets, L. Rudenko, M. Bagrov, S. Sonko, etc.). In spite of the fact that the national geographic establishment openly neglects methodological problems of geography, it (the methodology) nevertheless makes its way up above the ground, like shoots that lean towards the sun. This is confirmed by all attempts to develop a single concept of the environment. Such attempts testify to the fact that this problem can gradually move most other problems in the subject area of many sciences to the background. The processes associated with this were noticed by V. Vernadsky[1] and emphasized by one of the authors in the early 2000s (Sonko, 2003).

The fact that the authors of the above-mentioned article are anthropogeographers (representatives of economic, or, broadly speaking, social geography) is really significant. Perhaps the revival of in-terest in the integral essence of geography among anthropogeographers marks the transition of this science to a qualitatively new (old?[2]) level of interpretation of reality. This is obvious to a great extent, since the monographic study of both the centre and periphery relations (Pylypenko, 2015) and the basics of geo-planning (Topchiev, 2014) once would certainly have led the authors to understanding the integral properties of the Earth's space — without dividing it into 'the objects the study' of natural geographers and anthropogeographers — geospheres (Topchiev, Malchykova, Pylypenko, Yavorska, 2017), and without its vague attribution to 'the subject area' of either social or natural geography (Topchiev, 2004). The present-day fragmentation of geography, which used to be integral, is sometimes absurd. One may visit the site of 'Bibliometrics of Ukrainian Science'. In the section 'Earth Sciences' only the scientific preferences of physiographers (mainly geography and cartography, or the environment) (T. Bobra, M. Hrodzynskyi, H. Denysyk, I. Kovalchuk, etc.) are more or less adequately given an account of. As for economic geographers, perhaps only O. Topchiev appeared in the section 'Geography and Cartography' in the branch called 'Social Sciences". The rest of the representatives of this modern geography branch are at best marked as 'Geography and Cartography'. Most scientists are referred to the purely natural 'Earth Sciences', 'Environmental Sciences' and 'Ecology'. As a result, it gives an impression of the inappropriateness of 'discrimination' of both social and public geography.

We are convinced that it is anthropogeographers who have to be most concerned about the problem of the integral nature of the Earth's space.

[1] 'Nowadays, the framework of individual sciences, which scientific knowledge is streamed into cannot accurately determine the area of the scientific idea of a researcher and exactly describe his scientific effort. The problems that are of interest to him often do not fit into the framework of an individual, well-formed science. We specialize not in sciences but in problems' (Vernadsky, 1991).

[2] Did not the classic of economic geography N. Baransky in the 30s of the twentieth century urge that a territory (of a country or a region, etc.) be considered as a complex 'from geology to ideology'? Was not it our compatriot Serhiy Podolynskyi in the 19th century who emphasized the energetic essence of all economic processes, thus trying to implement truly objective (physical and economic) pricing mechanisms for goods and services in the world economic system? Taking into account the fact that it is economics and economic sciences that are the leaders in a complex system of developing natural resources of the planet (including its landscape envelope), it may be more appropriate to call oneself an economic geographer, rather than a social geographer or public geographer.

Eventually, these scientists will realize that the Earth's space from the very beginning was appropriately or-ganized by Nature itself. Various terms have been suggested for the interpretation of the Earth's space itself and its individual fragments, as well as for the science that would conduct its integrated study. In particular, various aspects of existence of the Earth's space today are explored in the context of the concepts of sociogeosystems (Nemets, Nemets, 2014), environmental studies (Holubets, 2015), neoecology (Nekos, Nekos, Safranov, 2011), anthropogenic landscape (Denysyk, 2001), intentional paradigm (Topchiev, Nudelman, Rudenko, 2012), ecogeosophy (Kyselov, 2015), etc.

In fact, the recent intensive growth of the debate on environmental studies also has another root – the civilizational one. There is an inevitable question that geographers of the anthropogenic and landscape branch (Yablokov, Levchenko, 2015) face today, in the era of radical man-made changes in the biosphere, — is it still safe to further 'scientifically justify' the change of natural landscapes by man? Is this safe as long as such 'scientific justification' gives a powerful tool to 'constructors' of the 'mining', 'uranium' and other landscapes for further human attacks on nature (Sonko, Maksymenko, 2016).

Material and methods of research. The research is based on the elucidation of the main provisions of the existing concepts of environmental studies that have features of integrity with respect to the natural sciences, the theoretical foundations of which lie in their basis.

In the course of the research, mostly philosophical and general scientific methods were used, including the logical ones (analysis, synthesis, comparison, deduction, induction), as well as dialectics.

The analysis was implemented at each stage of the research. When considering different concepts, their objects were determined and the content characterized, geographical and ecological components were compared. Synthesis, which is the dialectical opposite of analysis and is logically applied after the latter, consists in highlighting the common features of different environmental concepts that can form the basis of the integrated environmental study concept. Comparison of the analysed scientific constructions is an indispensable tool for extracting their common or similar elements.

The study used the deductive and inductive methods. In particular, the deduction manifests itself in taking the idea of creating an integrated environmental study concept as a starting point, and each item of individual natural science concepts was characterized in terms of its conformity with the general purpose of our research. The induction reveals itself in the selection of such provisions of each scientific construction, which can become 'building material' for the creation of an integrated concept of the environment.

Dialectics as a philosophical method is present in the research due to the application of the laws of unity and struggle of opposites (through a combi-nation of analysis and synthesis, deduction and induction), and the transition of quantitative changes to qualitative ones (due to the gradual accumulation of individual concepts in natural science, which, taken together, give the necessary facts and scientific provisions for the construction of an integrated concept of the geographic and environmental study).

The research made use of the historical method, in particular, when analysing the development of environmental ideas in time (from the noosphere by V. Vernadsky up to environmental studies by M. Holubets).

Results and their analysis. Taking into account the unsuccessful attempts of non-geographers to solve a purely geographical problem (the concept of 'environmental studies' by M. Holubets), one of the authors, considering himself to be an economic geographer (not even a social or a public geographer), solved this problem for himself 15 years ago (Sonko, 2003).

In fact, humanity has for a long time (approximately from the Neolithic period) exercised nature management of the noosphere on our planet. But if, before the Neolithic revolution, there had been natural landscapes on its daylight surface, after it *Homo sapiens* started to actively modify them, 'building himself' into the landscape envelope and forming anthropogenic landscape strips such as a 'forest field' (Denysyk, 2001) with ecotones — without explicit boundaries of natural zones. Approximately at that time, the search for the ways to justify such intervention, which was often destructive, began. Thus, in recent years, the landscape envelope, unrecognizably changed by man, has prompted scientists to develop an 'intentional paradigm', according to which the methodology of each science tries to take into account the role of man not only as a component of nature, but as a researcher who creates different branches of knowledge and sets respective subjective target guides for them (Topchiev, Nudelman, Rudenko, 2012). In our opinion, this is an obvious step back, as this emphasizes the return to the object-object relations between man and nature, which most modern landscape scientists (M. D. Hrodzynsky) rejected long ago in favour of the post-classical subject-subject ones (Maksymenko, 2018).

Therefore, the idea of the noosphere (almost two thousand years before the term appeared) 'embedded' in the Earth's atmosphere, has embarrassed geographers from the times this science appeared. Thus Strabo, the author of the world-famous 'Geography', understanding the many-sidedness of human existence on our planet, even in ancient times, considered himself to be 'not a geographer, not a histo-rian, but a philosopher' (Arsky, 2015). A. Hettner, with his idea of 'embedding' all things in existence into the Earth's space, considered this very earthly space with all the objects and phenomena present in it and interacting with each other to be the object of geographical studies. The links among them, according to A. Hettner, have a landscape, causal nature. A. Hettner also referred human society to similar systems of geo-objects. Some unique combinations of certain objects and phenomena in a particular territory lead to the emergence of geographic countries (choros, space) (Hettner, 1927).

However, the idea of 'transversality' was fully elucidated in the book by our contemporary O. Reteyum 'The Earth's Worlds'. He 'discovered' integrative (socio-natural) spatial entities ('chorions' and 'sphragis') on the daylight surface of the planet (the term by O. Kovalyov) and once again proved the right of the noosphere as defined by V. Vernadsky to exist. At the same time, being a physical geographer, O. Reteyum was constantly reinforcing this idea by examples of consortium relations in 'pure' (without humans) nature (Reteyum, 1988).

Dozens (or even hundreds) of scientists (not only geographers) can be listed as those who have come up with an idea of the integrity of the planetary structure (J. Lovelock, L. Margulis, V. Gorshkov, etc.). This idea turned out to be so obvious that even well-known movie makers (James Cameron, 'Avatar') succeeded in promoting it. Nevertheless, its real implementation into life, which gave rise to the 'strategy of sustainable development', in its twenties (Johannesburg, 2002) became deficient, which has been written about many times (Sonko, 2018).

The comprehension of the reclaimed Earth's space substantially transformed by the versatile activity of humans (at different levels — from the planetary up to the local level) is also carried out by ecogeosophy. The sources of ecogeosophy, which was founded at the end of the twentieth century, are 'classical' geosophy and modern ecology.

We used the epithet 'classical' in inverted comas with respect to geosophy, because even the age of this discipline — not only ecogeosophy — is less than a century. Geosophy is a philosophy of human space that explores spiritual aspects of the natural landscape's influence (conditionally, unchanged by man) on human communities, in particular ethnos. L. Gumilev considered ethnos to be a geographical, landscape phenomenon, and the landscape itself — its storage and nutritional medium (Gumilev, 2006). Consequently, geosophy is a science of landscape and ethnic interaction.

The synthesis of geosophy with modern ecology, which long ago evolved out of the former position of a branch of biology, becoming an independent science and, moreover, an extensive system of many bio-, geo-, socio- and technical ecological disciplines, is ecogeoseophy. If the scheme of geosophical regionalization of the Earth's space (Earthworld), based on the nature of landscape-ethnic interaction (Kyselov, 2011) became the logical result of our geosophical research, then the peculiarities of human space caused by more or less significant changes in landscapes as a result of economic and other types of human activities should be taken into account when conducting ecogeosophic research. In particular, in terms of ecogeosophy, the Donbas appears to be not only and not so much in the Donets Territory, a fragment of the steppe landscape and an extrazonal island of the forest steppe in the steppe for the territory of Ukraine, and, above all, a region with a predominance of 'anthropogenic' (according to the terminology of one of the authors (Kyselov, 2017) landscapes proper. Thus, this region seems to be taken out of human space, becoming a virtually unfit environment for the life of the landscape predetermined human communities - ethnoses. The example of the Donbas illustrates the discrepancy of ecogeophysical realia, which we will later depict in the form of sketch maps as already mapped geosophical earth-spatial formations.

The post-classical approach to the formation of the ecological network can be the confirmation of the anthropogenic component of landscape development (especially for the regions of old industrial development). According to this approach, not only natural objects but also the man-made ones must be bequeathed today, (Sonko, Kazakova, 2016).

We present the analysis of the above-mentioned modern environmental concepts, which more or less claim to be integral, in Table 1.

In our opinion, the main feature of all the environmental concepts analysed is their interdisciplinary nature. Mostly the tendencies for integration between geography and ecology (in particular, geosociosystemology, environmental studies, anthropogenic landscape studies, neoecology), as well as between ecology and noosphereology (in the concept of noosphere ecosystems), among geography, ecology and philosophy (with respect to eco-geosophy) can be traced.

Table 1. A Comparative Characteristicof Modern Environmental Concepts

Authors of the Concepts	Names of the Concepts	The Main Content
M. Holubets	The concept of geosoci-osystems, environmental studies	The need for the integration of natural sciences around the topical environmental problems, the consideration of man outside the biosphere (which is an environment for humans), the cross-cutting nature of the sciences studying the interaction of man and the biosphere at the theoretical level (geosociosystemology) and the applied one (environmental studies)
G. Denysyk	Anthropogenic landscape studies	The virtual absence of natural landscapes within the developed land of the Earth today, the acquisition of qualitatively new content by the landscapes in connection due to their anthropogenic transformation, the need for their study as anthropogenic geospatial systems
V. Nekos, A. Nekos	Neoecology	Non-traditional approach to ecology from the point of view of the leading influence of human transformational activity on ecosystems
K. Nemets, L. Nemets	The concept of sociogeosystems	Anthropocentric idea of sociogeosystems as geospatial social formations of different ranks
O. Topchiev	The concept of spatial organization of nature, population and economy, intentional paradigm	Consideration of man as a component of nature and at the same time a researcher who through his cognitive activity sets subjective target guides for it
S. Sonko	The concept of noosphere ecosystem	Consideration of '*Homo sapiens'* as an equal to others in carrying out his material-energy exchange in the biosphere
Yu. Kyselov	Ecogeosophy	Consideration of geospatial structures of the Earth's world with the account of not only the landscape-ethnic interaction in the natural environment, but also the type of nature management and the human-induced transformation of landscapes caused by it; geosophy of the explored space

Consequently, the focus of contemporary environmental studies and the greatest point of growth of the integrated concept of the environment lies at the intersection of geography and ecology. It should be emphasized that we mean unified geography without its traditional division into physical and socio-economic geography, since virtually all branches of modern geography have ecological content: physical (natural) geography studies the natural landscapes that served as the initial material for man in his diverse economic activity; constructive geography develops probable ways of formation of natural and anthropogenic geosystems in ecological equilibrium on the basis of anthropogenically transformed landscapes; socio-economic (public) geography is related to ecology through the doctrine of natural resources and territorial organization of economy. After all, most branches of economic activity have a greater or lesser negative impact on the environment: enterprises and heavy industry, especially mining, as well as motor transport, pollute the air and water environment; agricultural production neglecting environmental requirements and criteria, causes anthropogenic acceleration of erosion processes (both sheet wash and linear erosion) and soil contamination due to excessive application of mineral fertilizers and pesticides.

It is worth noting that some of the aboveconcepts have general geographic content (in particular, anthropogenic landscape studies, neoecology, the concept of noospheric ecosystems, ecogeosophy), which gives grounds for considering complex objects that are investigated with their application as integral systems of various geospatial ranks. At the same time, the concept of sociogeosystems has purely sociogeographical content, which also makes objects that are studied within the framework of this concept (sociogeosystems of various spatial ranks) subsystems of integral systems (such as noosphere ecosystems).

After the analysis of the undoubtedly important concepts of environmental studies, the main question of nature management — 'Why does the global environmental problem continue to get worse?' — still remains unanswered. Even recent fundamental treatises on this problem (Yablokov, Levchenko, 2015, 2016, 2017) do not give any hope for a constructive solution to it. Thus, the authors give an answer to the question 'What is going on?' in the first article of the series (Yablokov, Levchenko, 2015). The second article gives an unambiguous answer to the question 'Who is to be blamed?' There is no doubt, it is man (Yablokov, Levchenko, 2016). However, the third article of the cycle gives no answer to the question 'What is to be done?' The authors state that 'the contemporary discourse of social evolution, in spite of attempts to unite the enormous amount of facts and ideas in the field of development of human society, is still at the stage of substantiating hypotheses and distinguishing tendencies. All these efforts have not led to the creation of any comprehensive concept yet, not to mention a complete theory' (Yablokov, Levchenko, 2017).

We dare assert that such a concept (the concept of noosphere ecosystems) was developed by one of the authors 15 years ago (Sonko, 2003).

The essence of the concept of noosphere ecosystems is as follows (Sonko, 2010):

1. The main reason for the emergence and aggravation of the global environmental problem is the different development rates of nature and society. The search for and finding the specific Man ecotope and the study of its spatial evolution is a result of spatially and temporally different, or 'separated' in time and in space, states of nature and society. In order to constructively solve 'the global environmental problem', one must radically revise, first of all, the spatial existence of a man as a species , *Homo sapiens*. With this aim, one must find such areas of the Earth's space, in which the gap in the speeds of nature and society is 'captured', and in future bring them into the necessary correlation.

2. The aspiration for the state of the noosphere (at the present stage — 'sustainable development') with the course of the process of noospherogenesis should be carried out by Man within the spatial boundaries of the social-natural systems, which substantially represent ecosystems and have a double character of the boundaries. That is, these are such synergistic interconnections of natural and social components that are already evolving according to their own laws. Approximation of the territorial organization of society to the noosphere is proposed to be implemented in the form of possible scenarios at different spatial levels (Table 2). The existing strategy for creating an ecosystem should cover the meso- and macro levels. At the micro level, it is also necessary to implement a strategy of combining the boundaries of natural and agroecosystems, coordinated with the noosphere dynamics. Thus, we comply with one of the main conditions of the noosphere development — such a change in the structure and functions of natural ecosystems performed by man keeps them capable of self-reproduction.

3. One of the main noosphere provisions of theecology of *Homo sapiens* is that this species is an equal participant in the natural matter-energy cycle. But he has expanded the boundaries of his ecological niche due to the advanced timing of natural processes ('time traps', for example, prolonged storage of biomass in refrigerators, canning, etc., instead of their decomposing by reductions immediately after dying), spatial transformation of its ecotope ('space traps', for example, in the form of 'properly' organized crop rotation, contouring-reclamation systems of agriculture, etc.). Moreover, such a spatial-temporal transformation has considerably increased the level of the planetary entropy ('information traps' (Sonko, 2003a; 2003b; 2003c; 2003d).

4. *Homo sapiens*, in the process of his life in the biosphere of theEarth, forms spatial/edaphic systems which are ecologically identical with other types, and similarly participates in the food chains, occupying his trophic level in the ecosystems that are radically rebuilt in terms of space, but are, nevertheless, natural. 'Ecotope' of man goes beyond the limits of the organism level of organization of a species and occupies the population and even the ecosystem level. Therefore, it is more logical to talk about an agroecosystem as a modified ecological niche of *Homo sapiens* with unclearly defined (moving) spatial boundaries. Therefore, there is no reason to consider the agroecosystem (as well as other noosphere ecosystems) of *Homo sapiens* as unnatural (variants: 'semi-natural', 'combined', 'artificial', 'anthropogenic', 'technogenic'), based on the presence of 'the second nature', Man. All ecosystems, including anthropoecosystems (or the noospheric ones), are 'primordial'.

5. The uncertainty of the main guidelines of the concept of sustainable development, which in its present manifestation implies the unfair division of the global territory by 'civilized' countries according to ecological functions (Pozdnyakov, Tikunov, Fedotov, 2003; Protopopov, 2003), induces one to seek one's own concept of the noosphere development, based on the necessity of the methodological separation of the idea of reaching the noosphere state by socio-natural systems (sustainable development) and the idea of nature conservation (with the preservation of an anthropocentric attitude towards it). With the aim of approaching sustainable development, the priority development of agroecosystems, as ana-logues of the noosphere ecological niche of *Homo Sapiens* is viewed. There is a subsequent need to 'insert' the administrative-territorial division into the agroecosystem's bor-

ders, because in this case the chorological content of the interaction of nature and society will approach the optimal ones (Sonko, 2010). In order to implement the concept practically, a model of socio-natural interaction was developed. It is based on the principle of spatial rotation of the functions of urban and agroecosystems with the tendency towards not a barrier, but a contact (ecotonic) type of boundaries between natural and anthropic elements. At the same time, the pattern of the interaction between nature and society radically changes from the anthropocentric to the adapted one. Given the main content of the above concept, we must agree with the opinion of K. Losev and V. Gorshkov (Gorshkov, 1995; Losev, 2003) that the main guarantee of 'the noosphere' character of nature management should not be quotas for carbon dioxide emissions (Kyoto Protocol), but the successful support of self-reproduction mechanisms of natural ecosystems in certain countries.

Concerning agroecosystems, according to current estimates, the emission of carbon (as the main contributor to the greenhouse effect) from the world's agriculture exceeds its emissions from the combustion of fossil fuels by 10% (Losev, 2003). Therefore, modern agriculture is the main contributor to the greenhouse effect, and this impact will continue to grow in the context of the economic and demographic crisis. The practical solution to these contradictions is the rebirth of such communities of people in the countryside, which by the type of their spatial existence would be close to natural ecosystems. Radical changes in the spatial existence of humankind towards the natural economy will help stabilize the population growth, and will make nature management adapted to natural ecosystems (Sonko, 2017).

Noosphericism — is the doctrine of human society based on the noospheric principles, which consist in the comprehensive adaptation of nature management to natural mechanisms (Table 2). There are objective prerequisites for this. Thus, in rural areas of most countries, people are forced to the brink of survival, which urges them to return to the natural economy and the need to harmonize with the natural landscapes in which the family lives. There are new public initiatives of 'returning to nature' such as the ecological movement 'Ringing Cedars of Russia', manufacture of organic products, ecological settlements, etc. The consumption of natural substances and energy and the generation of biowaste are based on ecosystem principles. The consumption of the ecological resource of the planet 'is stretched' in time in order to ensure the proper conditions for future generations' life.

The spatial, ecological and social life of Man becomes a form of combination of local age-long traditions of nature management and the latest technology in which there are no entropy limitations. The result is a gradual return of the energy consumption of the human population to a level of 1%, which is in accordance with the laws of the ecosystem organization of living organism populations. The main ideas of the noosphere, adapted to the balanced nature management, correlate with the above concept of noosphere ecosystems.

Conclusions

- Activation of the problem of the environmental concept by anthropogeographers testifies to the fundamental integrity of the entire geographic science without its distinct division into natural and social (or physical and economic) geography previously dogmatically proclaimed by the Soviet methodology and ideology.
- A contemporary, adequate concept of the environment has not been developed yet. Its development and final design will require, above all, the rejection of the mechanistic perception of the surrounding world divided into objects and subjects of research.
- Within the framework of the main problem (the global environmental problem) of the article, it is geographers who must indicate in time and space such integrated environmental systems (socio-natural systems, the subsystems of which can be presented by natural landscape systems to varying degrees changed byman) that are formed as a result of the joint development of nature and society.

Table 2. Scenarios of Transition to Sustainable Development

Scenario Elements	Scenarios and Concepts of Nature Management			
	Conservative	Centristic	Scientific	Noospheric
The range of the planet's population (billion people)	0.5—1.5	8—12	30—50	8—10
The nature of urbanization	The level of urbanization decreases, econetworks develop instead of metropolises and big cities	Gradual stabilization of the number and size of cities, as well as the population of the Earth	The level of urbanization increases, big cities ecologize, including metropolises	The level of urbanization decreases, cities are preserved, but stop playing the role of 'a social creature', the net of ecosettlement expands
The change in the	Decrease by 6—10	Increase by 2—3 times	Decrease by 10 and	Gets stabilized at the ex-

volume of the world's power consumption	times		more times	isting level, but the structure of power consumption changes radically towards energy-saving
The structure of energetics	RE-based energy (Renewable Energy)	Polyenergetics: atomic, based on RE, thermal	The predominance of nuclear power	Basic — hybrid and alternative; supporting — atomic.
The nature of agriculture:	Economical	Moderately economical	Over-intensive	Economical and natural
- the share of arable land	Low (35-40%)	Moderate (up to 50%)	High (over 60%)	Low (35-40%)
- the system of agriculture	Organic. Mineral fertilizers and pesticides are not used.	Compromise. Mineral fertilizers and herbicides are used in moderate doses.	Intensive. Closed soil, high doses of mineral fertilizers, irrigation, monoculture are widely used.	Highly adaptive to local conditions, with a minimum number of energy subsidies.
- the variety of farm animals and the type of feeding	High variability, extensive feeding relying on natural forage grounds, growth stimulants are not used.	Moderate diversity, integrated feed rations with the use of forage from arable land, growth stimulants are not used.	Low diversity, intensive breeding of cattle, pigs, poultry with arable food, wide use of growth stimulants and other 'biochemistry'	Diversity according to local traditions, integrated feeding, adapted to local conditions (provided that the share of 'fodder arable land' is not more than 15%).
- transgenic varieties and breeds	Not used	Used in moderation	Widely used	Transgenic and introduced plants are either excluded completely or do not significantly affect the structure of cultural phyto- and zoocenosis.
- the peculiarities of agricultural products' consumption	Mostly no animal protein consumption in favour of the vegetable one	The diet is close to the current one	The diet is 'distorted' towards the further increase in the consumption of animal protein	The diet is balanced and meets local traditions
The main structural materials (and mineral resources)	Secondary	Primary and secondary with the development of resource-saving technologies	Replacement of finite resources with their new equivalents	Replacement of finite /exhaustable resources with their new equivalents that will be capable of biodegradation upon completion of use
Environmental pollution	Minimal due to the closure of all environmentally unfriendly industries and the implementation of non-waste technologies	At the current level	Moderate due to low-waste technologies, improved treatment facilities and disposal of especially hazardous waste	Minimal due to de-urbanization, transition to new construction materials, reduction of the general level of consumption and introduction of a significant share (up to 40% of GDP) of the natural economy.
Biodiversity protection	Complete preservation	Preservation of a larger part	Preservation of 50-70%	Gradual withdrawal from agroecosystems in their present form in favour of adapted forms of nature management
The share of protected natural territories on the planet	70%	33%	Less than 10%	The need for the introduction of protected areas is gradually disappearing

The prospects for the productive development of environmental science are related to the concept of noosphere ecosystems, which has been developed by one of the authors over the past 25 years (Sonko, 1992-2018) and can become anintegral part of the content of ecogeosophy, the theoretical and methodological principles of which have been improved in treatises of another author (Kyselov, 2015).

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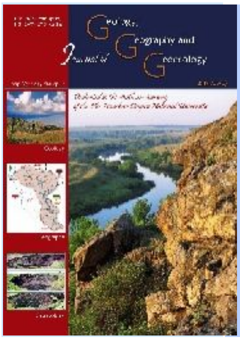

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Natural-historical and ecological analysis of land resources and land use in Lugansk region

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The recent but intensive economic development of the region has led to the formation of a modern land use structure, caused both by natural and historical factors. The destructive anthropogenic impact on the geomorphosphere has led to the degradation of soils and the degradation of the land fund. A retrospective analysis of the problem can reveal the causes and consequences of the land use system established in the region and suggest some adjustments to land management and land use policies. The influence of human economic activity (in particular, agriculture and the coal industry) on the nature of land use in the Lugansk region is considered (separately for the right bank and the left bank part thereof). The significance of the extent of ravines in the territory and the surface washout in the process of degradation of soils and lands is emphasized, which is especially expressed on the Donetsk ridge (right bank of the River Seversky Donets). The role of the semi-mountainous terrain of the Donetsk ridge as a natural factor in the spread of erosion processes is noted. A brief historical review of attempts to combat the development of ravines in Lugansk region, which have been conducted since the second half of the nineteenth century, is presented, but the vast majority of these efforts were not effective. One of the negative factors that influenced the structure of land use is the removal of an increasingly large area from use as grazing land, which increases the intensity of erosion processes. The destructive influence of mine production on the structure of land use in the studied region is highlighted. We note the ecological consequences of physical alienation of lands as a result of their occupation by waste heaps and other anthropogenic forms of relief, formed by the mining industry. It is emphasized that not only the mines themselves, but also concentration of factories, communication structures, etc. play a role in reducing the area occupied by agricultural land, and therefore cause a negative change in the structure of land use in the right-bank part of the territory of Lugansk region. It is noted that extensive and excessive intensive land use in agriculture and the coal mining industry in Lugansk region have led to the degradation of large areas of land and impoverishment of the land fund. It is stressed that the current structure of land use requires radical changes which should be based on new conceptual principles and a systematic approach to the problems of nature management.

Key words: land resources, land fund, land plot structure, land use structure, land management, land degradation, landfill, extensive use of land, nature use.

Природно-історичний та екологічний аналіз земельних ресурсів та землекористування в Луганській області

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Недавнє, але інтенсивне господарське освоєння краю призвело до формування сучасної структури землекористування, зумовленої як природними, так і історичними факторами. Деструктивний антропогенний вплив на геоморфосферу призвів до деградації ґрунтів і зубожіння земельного фонду. Ретроспективний аналіз порушеної у роботі проблеми дозволяє виявити причини та наслідки усталеної в реґіоні системи землекористування та вносити певні корективи в політику землевпорядкування та землекористування.Розглянуто вплив господарської діяльності людини (зокрема, сільського господарства та вугільної промисловості) на характер землекористування в Луганській області (окремо для правобережної та лівобережної її частин). Наголошено на значенні заяруженості території й площинного змиву в процесі деградації ґрунтів і земель, що особливо виражено на Донецькому кряжі (правобережжі Сіверського Дінця). Відзначено роль напівгірського рельєфу Донецького кряжа як природного чинника поширення ерозійних процесів. Наведено короткий історичний огляд спроб боротьби з розвитком ярів на Луганщині, які проводилися, починаючи ще з другої половини XIX ст., але в переважній більшості не були ефективними. Як один із негативних чинників, що вплинули на структуру землекористування, окреслено відведення дедалі більшої площі під пасовища, що підвищує інтенсивність ерозійних процесів. Висвітлено згубний вплив шахтного виробництва на структуру землекористування в досліджуваному реґіоні. Зауважено щодо екологічних наслідків фізичного відчуження земель внаслідок їх зайняття породними відвалами, териконами та іншими антропогенними формами рельєфу, утвореними гірничопромисловою діяльністю. Підкреслено, що не лише власне шахти, а й збагачувальні фабрики, комунікаційні споруди тощо відіграють певну роль у зменшенні площ, зайнятих сільськогосподарськими угіддями, а отже – викликають негативні зміни структури землекористування у правобережній частині території Луганської області. Відзначено, що екстенсивне, а також надміру інтенсивне землекористування в сільському господарстві та вуглевидобувній промисловості в Луганській області призвели до деградації великих площ земель та зубожіння земельного фонду. Наголошено, що сформована структура землекористування потребує радикальних змін, які б мали базуватися на нових концептуальних принципах і системному підході до проблем природокористування.

Ключові слова: земельні ресурси, земельний фонд, структура земельних угідь, структура землекористування, землевпорядкування, деградація земель, площинний змив, екстенсивне використання земель, природокористування.

Introduction. Problem setting. Land resources are the most important part of the natural environment, which predetermine the existence and use of all other natural resources. At the core of all types of nature management is the land use system, which is formed under the influence of natural, historical, ethno-cultural, socio-economic factors, which lead to a combination of different areas of land use and the formation of a particular ecological situation.

Extensive methods of using natural resources, including land, have led to the development of a number of destructive processes, the deterioration of environmental quality of the environment and unidirectional land use.

In Lugansk region an almost practically catastrophic situation has developed in the area of land use associated with intense violent use of land in agriculture and the mining industry.

Economic development of the eastern territories of Ukraine began later than the rest of its territories and took place quite intensively. The heterogeneity of the natural conditions of various parts of the modern Lugansk region caused differences in the nature of management, and, consequently, different pressures on the natural environment, in particular, on land resources. The nature of the relief and climatic features of the left bankof the River Seversky Donets led to the development of agriculture, intensive ploughing of land with all the negative consequences. On the right bank of the River Seversky Donets, in addition, due to the unique geological structure of the area, the mining industry has concentrated - again, with significant negative environmental consequences. The main pressure fell on the geomorphosphere, or more precisely, on the pedosphere - due to reduced agricultural use, soil degradation, fertility decline, physical reduction in the area of fertile soils, deterioration of the physical and chemical properties of the soils, and consequently - loss of crop, pollution of all components of the natural environment, deterioration of the sanitary and hygienic living conditions of the population, etc. That is, a number of environmental problems arose, which for Lugansk region, in the current conditions, have become a matter of special urgency.

The land use structure requires radical changes not only because of the impoverishment of land due to inefficient use of the land fund, but also due to the destructive events in the region associated with the recent war and the temporary Russian occupation of part of the territory of Lugansk region, which together have led to tragic consequences both in society and in the natural environment.

A retrospective and up-to-date view of these problems can reveal the causes and consequences of the existing land management and land use system and make constructive conclusions.

The above mentioned postulates lead to the relevance of the chosen topic of study.

The purpose of the work is the natural-historical and ecological analysis of land resources and land use in Lugansk region, identifying the causes and consequences of the impoverishment of the land fund - the basis of the socio-economic development of the region.

Tasks that were delivered:

- to identify and analyze the influence of natural-historical conditions of the region on the formation of land use structure;
- to make a description of the structure of land use and its changes in time;
- to create a base of basic indicators that reflect the state of land use and trends in its changes;
- to determine the nature of the negative impact of existing approaches to land use in the region;
- to substantiate practical recommendations aimed at optimizing the land use structure in the region.

The object of scientific research is the land resources of the Lugansk region.

The subject of scientific research is the structure of land use, its changes over time, in particular the state of land used in agriculture and industry.

The methodological basis of scientific research is the laws and principles of dialectics; the basic methodological basis is the systematic approach as a means of studying the interconnections and interdependencies in the system of nature - society. In conducting this research, we use such methods as logical (analysis, synthesis, comparison, deduction, induction), historical-geographical, mathematical-statistical, descriptive, cartographic, cardometric.

The novelty of the scientific research lies in the geographic approach to the study of land use in Lugansk region - a region that has been overexploited by economic development, excessive agricultural pressure on landscapes and destruction of the natural environment for the development of the coal mining industry.

The practical value of scientific work is to critically evaluate the current structure of land use in agriculture and industry; identifying the causes and trends of its changes; identification of ways to optimize the land use structure for the conservation and rational use of the natural resources of the region.

The main material of scientific research. Lugansk region, which is the territory of our scientific research, is located in the far east of Ukraine. Even the visual analysis of a physical map (Fig. 1) proves the spatial heterogeneity of its surface. The territory of the region is clearly divided by its main water artery – the River Seversky Donets - into the left bank and the right bank. In the morphostructural plan, the left bank is represented by the Starobelskaya plain (the southern spurs of the Central Russian Highland), which was formed on the ancient foundation of the Voronezh anteclase. The Starobelskaya plain is dissected by river valleys of submeridional stretching and ravines. Here on the Cretaceous-marl rocks a soil cover formed, represented by ordinary black soils.

Fig. 1. Physical map of Lugansk region

The right bank of the south of the studied region is represented by the Donetsk hills, which within the Lugansk region is the northern macroslope of the Donetsk ridge, the main Donetsk watershed, and, in part, the southern macroslope of the Cretaceous. This morphostructure due to the specific tectonic processes that took place in geological antiquity is characterized by the complex and original relief of the structural-denudation plain - a distinct alternation of the basins in the watersheds, where typical black soil types were formed on forest non-carbonate rocks. Significant vertical and horizontal fractioning of the surface associated with the tectonic activity of individual areas of the territory and active geomorphological (first and foremost, erosive) processes led to the formation of slopes of different steepness, in which later, due to human economic activity, negative geomorphological processes became accelerated.

In the abovementioned morphostructures, depending on the characteristics of the relief and regional climatic differences, various types of land have been formed - water divisions, watershed slopes, ravine slopes, floodplains, etc.

The nature of lands depends on many natural factors, among which geological (determining role of the parent rock), climatic (temperature regime and humidity), as well as morphometric characteristics of the relief occupy a significant place.

The investigated region is located in a temperate climatic zone, and its geographic location results in a large amount of heat flow: on the left bank of Lugansk region, the average annual total solar radiation is 95-110 kcal / cm², on the right bank of Lugansk region – 105-114 kcal / cm² (Atlas prirodnih usloviy i estestvennyih resursov Ukrainskoy SSR, 1978).

The climatic conditions of the left bank of Lugansk region are characterized by features of latitudinal zonation, on the right bank of Lugansk region the increased and strongly dissected relief creates certain azonal features of the climate (Table 1).

Table 1. Main climatic characteristics of the study area (Atlas prirodnih usloviy i estestvennyih resursov Ukrainskoy SSR, 1978)

The region	Average annual temperatures	Average January temperatures	Average July temperatures	Average annual rainfall
Left bank of the Lugansk region	+ 7° C	– 7, – 8° C	+ 21, + 22° C	450 – 500 mm
Right bank of the Lugansk region	+ 6, + 7° C	– 6, – 7° C	+ 21, + 22° C	500 – 550 mm

The amount of rainfall in the Lugansk region, fluctuating within considerable limits, both seasonally and geographically, depends to a large extent on the degree of fractioning of the area and the exposure of the slopes. The most humid part of the region is the Donetsk ridge, especially the main Donetsk watershed and the southwest macro slope, where more than 500-550 mm falls per year. Thus, the orographic factor creates significant azonal deviations in the hydrothermal regime of the territory. The relatively large amounts of rainfall on the Donetsk ridge creates favourable conditions for the spread of water erosion, especially since in the warm period rainfall is twice as high as in winter, and the intensity of summer precipitation far exceeds that of winter.

The territory of Lugansk region can be called the region of both the old and the newest economic development. On the one hand, almost three thousand years ago, various nomadic tribes inhabited from what is now Lugansk region, and in the beginning of our era our people settled on the path of transition from nomadic pastoralism to sedentary agriculture. However, this ancient economic development had a minimal impact on the state of the natural environment, since the land was used mainly for pasture and hay and - to a much lesser extent – for cultivation of crops, and was interrupted by the invasion of aggressive nomads.

For thousands of years now, Lugansk region had almost no permanent population, actually becoming a «Wild Field», which contributed to preserving the primitive steppe and forest (flood and ravine forests) landscapes, which existed even when the lands of the Dnieper Ukraine were agrolandscapes.

A new stage in the development of the territory (mainly agricultural, but also associated with the extraction of iron and copper ores) began in the late 16th and early 17th centuries, when Lugansk region from the west was gradually settled by Ukrainian peasants and cossacks, from the east – by the Don cossacks, and from the north –«people who had served in the army». But the predominant nature of land use until the end of the 18th century was agricultural production.

Economic development of the lands of the modern Lugansk region began with agriculture, which was associated with favourable natural conditions and rich natural resources - temperate climate, fertile lands, large areas of forests adjacent to the valleys of navigable rivers and large ravines.

The bulk of the inhabitants of the Slobozhanshchyna and the Donetsk steppes were engaged in working the land. There were two systems of farming: the three-field system and the cross-flow system. In the presence of large reserves of land, the peasants used a cross-flow system, which was gradually replaced by the three-field system, in which the land was divided into three parts: two of them were cultivated and sown, and the third was left fallow. Subsequently, alternation of tilled sites took place. After two years of cultivation, the land for the third year remained free, «resting» (Podov, 2004). Such a system was due to the fact that there was plenty of land, and there was no sense in tackling the problem of preserving its fertility.

In the first half of the eighteenth century, only a small part of the land was cultivated. As the settlement and development of the territory increased from the middle of this century, the crop area began to expand. The peasants were thrown onto waste land, moving to new, virgin lands. Gradually, the area of tilled land moved on the slopes of river valleys and large gullies, and broke the ground floor. Steppe fires and unregulated cattle grazing led to a disturbance of the turf cover, physical extinction of land under building, roads and so on. Extensive forms of land tenure led to a low yield of grain crops.

The systematic impact of man on the environment was amplified, which served as a forerunner of the imbalance in the landscapes of the region. This was especially noticeable on the land, as the most vulnerable component of the natural environment.

Since the beginning of the economic development of the present-day territory of Lugansk region, the land began to collapse. According to the general survey conducted in 1789-1804 , and presumably up to 1861, the extent of cultivation in the territory did not exceed 1 – 2 % (Fondovi materialy Derzhavnogo reg'ional'nogo geologorozviduval'nogo pidpryjemstva «Shid-DRGP», 2014). After the reform of 1861, the mass settlement of our region began, resulting in a sharp increase in the area of arable land, which by the end of the nineteenth century had already reached 3.1 – 4.5 % (Lyashenko, 1952). And at that time there were first signs of the destruction of land. Thus, at the beginning of the formation of the agrarian economy in the territory of our region (within the limits of the modern administrative area), specialists counted about a thousand gullies.

After the reform of 1861, the rapid development of industry began in the province. This was facilitated by the presence of enormous natural resources, which at that time were not only explored, but already developed. In 1722, deposits of coal were discovered in the present Lysychansk area. A little later ore was discovered and the first blast furnaces built , which were soon abandoned.

However, the qualitative structure of nature on the territory of Lugansk began to change, because of the spread of coal mining. At this stage, human activity in the natural environment was leading to significant changes.

With the discovery of coal deposits, this region began to be formed as an industrial one, which had a certain imprint on the structure of land. After all, the area of land unsuitable for agricultural use increased due to both underground workings and ploughing of the land.

In 1871, outstanding researcher I. F. Levakivsky noted that in the Lisichansk region of the Bahmut district «there are plenty of ravines, they occupy an area of up to 40 dessiatins out of the total the area of the estate of 648 dessiatins, not counting balkis ...» (Levakovskij, 1871). Since there is no reason not to suppose that this area was atypical for the entire Lisichansk region, both naturally and in terms of development, we assume that the area occupied by ravines was at that time already more than 6 % of the entire region. And the plundering of new territories, mainly of sloping lands, the formation of numerous boundary structures, field roads led to further acceleration of erosion processes.

The agricultural development of the lands in Lugansk region has its historical reasons. This was an increase in the demand for and export of bread and the further growth of the population of the region, which inevitably led to an increase in the area of arable land, and hence - to the destruction of natural vegetation, reduction of the areas of virgin steppes, which in turn led to the emergence and strengthening of erosion processes: natural erosion, which was caused only by natural factors and not of a catastrophic nature, received a powerful impetus and changed to a more intense accelerated or anthropogenic process.

Due to the development of coal mining, the southern part of the Lugansk region was populated more intensively, and on the Donetsk ridge, where virgin steppes were confined to the watersheds with developed ridges and hollow relief, the hollows and slopes were exploited, which contributed to the further development of erosion processes. I. F.Levakivsky noted that the most depleted slopes with washed- out soils and gulleys were distributed near settlements, which clearly testifies to their anthropogenic origin (Levakovskij, 1871).

The tilling of new and new territories, including the slopes, the creation of numerous boundaries led to the further development of accelerated erosion. I. F. Levakivsky gives the following example: «In 1890, in the autumn, a boundary ditch was dug in the direction of the slope; by the autumn of 1891, a moat of about 40 sazhan in length two-quarters of its depth and the same width had formed from this trench» (Levakovskij, 1871). It was near the Nagolno-Tarasivske village, located in the central part of the Donetsk ridge.

In the northern part of Lugansk region (that is, on the left bank), which, from the middle of the XVII century, was populated mainly by people from the Zadnieper Ukraine, the settlements concentrated along rivers and large ravines (balkis). Since there were no mineral deposits there yet, the peasants raised grain, vegetables and bred cattle. The long-term erosive fractioning of the land here began to increase due to human economic activity, and the steppes retreated to the watersheds, natural rich pastures suffered intensive and unregulated grazing of cattle, on the slopes erosion took place and gullies formed.

The formation of gullies became more and more intensified due to the fact that the lands were affected by erosion, the peasants took over new areas, the so-called «wastelands», but also the erosion processes did not stop on the abandoned lands because there was already a shift of soil through the destruction of the turf cover, mainly on sloping surfaces.

An unimaginable and unreasonable ploughing with all the consequences «has a historic prescription and its historical reasons: first, the possibility of selling grain crops and their continuously growing exports, and further - population growth – led to the continuous increase in the area under the plough» (Lyashenko, 1952). The increase in the area of arable land led to the destruction of natural vegetation, reduction of virgin steppes, which further intensified erosion processes (natural erosion changed to more intensive accelerated or anthropogenic erosion).

In the Donbass, where virgin steppes were confined to watersheds with ridges and ridges and hollow relief, the hollows, and slopes were exploited, which again contributed to the development of erosion processes. V. I. Taliyev (Taliev, 1896) noted that most of the depleted slopes with washed-out soils are found near settlements, which is further evidence of the anthropogenic origin of erosion. The same idea was stated by E. M. Lavrenko, who linked the existence of large areas of stony empty lands with environmentally unfriendly human activities (Lavrenko, 1926).

The abandoned eroded lands, which were previously under cultivation, were destroyed . Unregulated cattle grazing had a fatal influence on the state of the turf cover. Even in hilly forests that play a reclamation role and contain rich feed resources, cattle grazing led to a disturbance in the turf cover, washing away of forest soils, exposure of the root system of trees and shrubs, young growth was eaten by cattle, the forests were disturbed, gradually losing their water conservation and forest-melioration value. The names of some ravines - Gorihova, Lipova and others - indicate the destruction of forests in order to increase the area of arable, garden and meadow lands. On the slopes of these ravines so-called «unfit» land formed. There is no indication of nut and lime wood vegetation.

The solid runoff that has increased as a result of erosion has aggravated the hydrogeological conditions of the once navigable Donbas rivers. Erosional runoff, which in large quantities is carried out from ravines and gullies, caused silting of rivers, waterlogging them in some areas. And the surface runoff from the ploughed slopes reduced the humus horizon and worsened the quality of soils.

In particular, the archival materials of the report of the forestry director V. Reykha, the director of the Lugansk Sand and Gulley district of the Donetsk Land Department in 1918, testify to the problems of the Donbass in general: «It is too well known to everyone that the growth of gullies causes inconvenience to the plowman , the. In particular, in our area, they are simply a problem for any peasant, because it is absolutely impossible to find any roads in the area which are not slashed by this or that ravine. According to the survey, I can say that in our district there are about 3 thousand gullies which steal land the peasants, almost a tenth of the total land in the district, that is about 34 thousand dessiatin» (Derzhavnij arhiv Luganskoyi oblasti).

Another «Report on the accelerated formation of gullies in the past, present and future» by 1918 (Pirko, 2003) also noted that, according to the survey, Slavyanoserbsk region had more than 3 000 gullies areas occupying over 3 000 dessiatin.

The fractioning of the growing area and the growth of areas unsuitable for agricultural use caused a decrease in ploughing. The misfortune caused by the ravines became so significant that they were one of the causes of the poor crop yield. In particular, the reason for the crop failure in 1891, which covered twenty of the best grain-producing provinces of the Russian Empire, «many believed ... drainage and destructive action of the ravines» (Shikula, 1961), which gradually formed from the previous economy. Destruction of any woody vegetation in the steppe areas and the ploughing of steep slopes of valleys and ravines led to a decrease in moisture in the soil.

It should be noted that the intensification of erosion processes in the province began in the second half of the nineteenth century, that is, much later than in the whole of European Russia. Intensive tillage, inappropriate agricultural equipment, fragmentation in combination with peculiar natural conditions (significant fractioning by spread of the long established erosion area, large areas of steep slopes, weak resistance to soil erosion, the nature of precipitation, etc.) caused such a rate of development of erosion that by 1917 the situation had become catastrophic. In order to maximize the benefits of land at minimum cost, eroded plots were abandoned and new ones taken up, which was not something new in the then land-use system. «Unsuitable» land used for grazing livestock, turned into stony wasteland and was finally removed from household use. Thus, the increase in the area of agricultural land eventually led to its reduction.

The semi-mountainous nature of the relief of the right bank of Lugansk region, especially its highest part - the Donetsk ridge, was not favourable for agricultural development, and therefore, for a long time, there were no numerous permanent rural populations here. Yet, the right bank of Lugansk region with some delay, still experienced the same changes in the landscape of the environment as the left bank, which was also associated with agricultural development of the territory. Naturally, despite the development of the mining industry prevailing on the right bank of Lugansk region and agricultural production, it also played a role in the degradation of the land fund. Fertile black soils, confined to the main Donetsk watershed, were intensively exploited, which, together with the negative natural processes, could not fail to provoke their rather rapid decrease in soil fertility. The lands have undergone a massive violent agricultural load. As a result of the combined effects of various anthropogenic factors, there is a greater transformation of the natural environment, and hence the environmental stress on land resources is greater.

It cannot be argued that no attempts were made to improve the situation, but they were local in nature. All attempts to counter the effect of erosion by means of planting forests without combining them with agrotechnical measures proved ineffective (Fondovi materialy Derzhavnogo reg'ional'nogo geologorozviduval'nogo pidpryjemstva «Shid-DRGP», 2014). The main task - a comprehensive regulation of runoff and protection of soils throughout the entire catchment area - remained unresolved.

M. A. Rozov noted that on the Donetsk ridge a whole complex of extremely favourable conditions and reasons for erosion was formed. In his opinion, Lugansk region was the area with the most ravines: «... the uplands that diversify the relief, intensive plowing, the lack of forests, also the pronounced continental climate - all this contributed to the formation of many gullies» (Rozov, 1927).

This assessment of the territory of the Donbas in the erosive aspect is confirmed by E. E. Kern, who distinguished Ekaterinoslav province, and especially the Bahmut region, as an area with a lot of ravines. In many areas, he wrote, «the land under ravines was from 5 to 30 % of the total area» (Kern, 1928).

After the Second World War, anti-erosion measures were carried out on a limited scale and limited to reclamation. Their effect was insignificant because of the ploughing up of «virgin» lands. Further measures were not effective; there was no systematic fight against erosion in the Donbas.

Environmental conditions in our region unfavourable to agriculture and the high level of economic development have led to an aggravation of the problems of rational, ecologically sustainable use of natural resources, protection and reclamation of land in one of the old industrial regions of Ukraine - Donbass, which includes almost half of the territory of Lugansk region.

It is known that in the case of extensive economic management, the structure of land use, which has been formed for a long time, is often violated; in particular, the ratio of stabilizing and destabilizing components of the land fund changes.

According to statistical materials (FondovimaterialyGolovnogoupravlinnjaDerzhgeokadastruvLugans'kijoblasti, 2016), the lands of Lugansk region are divided into agricultural land, forests and forest cover, built- up land, open wetlands and dry lands with special vegetation. The area of agricultural land is 73.3% of the total territory of the administrative region. Cultivated land accounts for 97,6% of the agricultural land. In turn, in the structure of agricultural land, tilled land occupies 66.6%.

Purely natural and sustainable are forests; under certain conditions relatively stable stands are planted forests, hayfields and pastures. Lands which should be considered unstable are those that, having undergone to some extent the influence of human economic activity, have experienced a significant transformation, changed their properties (arable land, forest park areas, etc.).

The structure of the land consists primarily of agricultural land, the area occupied by forest, pastures, meadows, marshes (Table 2). The correlation between them in different physical-geographical and historical conditions may be different, and this is determined by their stability.

In the scientific agrarian literature, in addition to such an indicator as the stability of the land, environmentally stabilizing and destabilizing lands are also distinguished.

Among the aforementioned types of lands, the lands which stabilize the environment include hayfields, those which we consider destabilizing include pastures and arable land, which are most affected by mechanical (pasture) and agro-technical (arable) pressure. Our calculations found that the ratio between them is 1: 3.

Thus, we arrive at the conclusion that in the ratio of agricultural lands in Lugansk region destabilizing components prevail, mainly arable land.

Table 2. The structure of the land fund of Lugansk region at the beginning of 2016 (Fondovi materialy Golovnogo upravlinnja Derzhgeokadastru v Lugans'kij oblasti, 2016)

№	Type of the land	Area (thousand hectares)
1	Agricultural land	1955.75
2	Forests and other forest areas	356.28
3	Land of nature conservation designation	128.46
4	Open wetlands	16.56
5	Lands under recreational designation	188.15
6	Built-up land	22.06
7	Dry open lands of various types	1.10
8	Total area	2668.37

Thus, the analysis of the structure of the land resources of Lugansk region shows the high agricultural development of the territory, insignificant forest cover and the obvious imbalance between the lands that are in intensive agricultural use and the environment of stabilizing natural lands.

In absolute terms, the level of agricultural land cultivation in Lugansk region significantly exceeds the calculated norm. According to V. Medvedev and S. Buligin, the maximum permissible level of cultivation, expressed in an entropy measure, is 38.2 % (Medvedyev, 1992). In Lugansk region, it exceeds the calculated almost twice, and the continued trend is to increase the area of arable land.

But it is especially dangerous to increase the area of agricultural land, in particular arable land, on erosion-prone slopes with a steepness of more than 2 ° (Table 3).

Table 3. Distribution of agricultural lands on slopes of different steepness (Fondovi materialy Golovnogo upravlinnja Derzhgeokadastru v Lugans'kij oblasti, 2016)

Year	Kind of land	Slope steepness 0 – 2 °	Slope steepness 2 – 5 °	Slope steepness 5 – 10 °	Slope steepness 10 – 15 °	Slope steepness > 15 °
1972	Agricultural land	17.88%	34.73%	1.78%	1.37%	0.04%
	tilled land	20.95%	33.17%	0.74%	0.02%	—
1982	Agricultural land	49.59%	45.23%	4.96%	1.01%	0.05%
	tilled land	54.8%	43.74%	1.36%	0.01%	—
1998	Agricultural land	53.75%	37.37 %	7.05 %	0.86 %	0.15 %
	tilled land	26.89 %	57.25 %	14.69 %	0.18 %	—

From the table it follows that the area of agricultural land on the slopes from 5 ° to 10 ° over 26 years increased by 5.27 %, and on the slopes over 15 ° - by 0.11 %. The area of tilled land increased by 6 % at predetermined areas, on erosion-hazardous (slope over 2 °) - by 24 %, and on catastrophically erosion-hazardous (steepness of 10 - 15 °) - by 0.16 %. The result is that in the 35 years (1965 - 2001), the area of eroded arable land in the Lugansk region increased from 54.7 % to 66.5 %, which is more than twice the national average. At the same time, the erosion of the steep slopes reached critical, even catastrophic, magnitudes (Table 4).

Table 4. Erosion of arable land on slopes of different steepness in Lugansk region by % (Fondovi materialy Golovnogo upravlinnja Derzhgeokadastru v Lugans'kij oblasti, 2016)

Total eroded tilled land on slopes with different steepness, %					
0 – 1°	1 – 2°	2 – 3°	3 – 5°	5 – 7°	> 7°
33.83	57.80	95.14	98.40	98.40	98.27

The structure of the land is also changing due to the development of linear erosion, the formation of gullies, which is greatly facilitated by geological and geomorphological conditions in conjunction with climatic conditions.

For a long time, the structure of agricultural land has changed due to the removal of part of it for industrial and social needs. Changes to some extent have also concerned arable land, the qualitative state of which has deteriorated due to the cultivation of steep slopes with a washed out layer of soil.

The qualitative state of agricultural lands directly depends on the structure of the land fund itself (Table 5).

It is known that the area of surface washout leads to a decrease in soil fertility due to the deterioration of the physical and chemical properties of the soils themselves and air and water regime. Data on the intensity of surface washout on the territory of modern Lugansk region for the past century are absent, but modern studies indicate the gradual and steady nature of this process. Currently, about 64 % of agricultural land in Lugansk region suffers from surface erosion. The extent of washout of soils ranges from 30 to 70 %. Accordingly, the area with averagely washed out soils is equal to 15.3 %, and with significantly washed out soils – 8.6 % of the total area of the region (Kiselova, 2006). Yields on insignificantly washed out soils decrease by 30 %, on averagely washed out soils by 30 % to 50 %, and on significantly washed out soils by 50 % to 70 % (Medvedyev, 1992).

Table 5. Qualitative state of agricultural lands (Fondovi materialy Golovnogo upravlinnja Derzhgeokadastru v Lugans'kij oblasti, 2016)

№	Name of indicator	Agricultural land, thousand hectares	Tilled land, thousand hectares
1	Total agricultural land	1955.75	1276.5
2	Saline	87.9	39.7
3	Swamps	15.1	1.3
4	Stony	41.7	20.2
5	Prone to subsidence	1623.0	1265.0
6	Eroded	1195.3	902.7

Erosion processes and, in general, soil degradation are reflected in the content of humus in soils. Annual loss of humus is 0.45 %. Analysis of data from the State Environmental Protection Agency in Lugansk region over the past 20 years reveals a clear tendency to reduction in the content of humus. One can assume that if in one year this reduction is equal to 0.024 %, then in 50 years it will come to 3 %. The potential threat of erosion is 5.5 t / ha / year (Fondovi materialy Derzhavnogo reg'ional'nogo geologorozviduval'nogo pidpryjemstva «Shid-DRGP», 2014).

Despite the different conditions of nature use in the various natural and economic areas of the region (Donetsk ridge - right bank part of the region, Zadonets steppe - the left bank part of the region), the structure of the land in them differs little (Table 6), which given the significant mining pressure on the territory of the right bank, testifies to the greater environmental stress on the pedosphere in this region.

The problems of land use in the southern part of Lugansk region where industrial coal mining been conducted for more than two centuries are catastrophic .

Table 6. The structure of land under natural and economic areas in % (Fondovimaterialy Golovnogo upravlinnja Derzhgeokadastruv Lugans'kij oblasti, 2016)

№	Natural-economic areas	Agricultural land	Including the:				
			tilled land	perennial plantations	forage lands	forests	other
1	Donetsk ridge	73.5	57.2	0.9	15.2	4.9	21.8
2	Zadonets steppe	85.4	65.2	1.0	19.2	4.6	10.0

The direct impact of mining production consists in the burial of soil cover under heaps and dumps, destruction or reduction of agricultural and forest lands, changes in the nature of the surface (in particular, the formation of depression forms of relief, and in areas close to the occurrence of groundwater – waterlogging of the territory), the construction of various man-made structures, laying of communications, etc. Dumps alone in the oblast occupy 4.18 % of the territory.

Indirect effects appear in changes in the regime and the state of surface and groundwater in connection with the flooding of closed mines, the intensification of the infiltration of toxic substances into the soil through the dumps of the «empty» rock, tailings, increasing the volume of water intakes in the river valleys, etc. Due to the drainage of rain through the dumps and heaps, in particular drainage water, and as a result of the temperature rise during combustion of the rock, chemical reactions in the aquatic environment are catalyzed, resulting in the slag heaps affecting locally the deterioration of surface and groundwater, and through them - the physical and chemical properties of soils (Zhulanov, 1981). It should be noted that such indirect influence of the mountain masses raised on the surface, affect the environment at least to an area that is 0.7 % of the area of Lugansk region.

Negative influence of rock dumps , especially when active and smouldering, on soils occurs also through the atmosphere. So, under the influence of flue gases, dust changes the properties of soils, the saturation of particles that settle down from the smoke cloud occurs, and as a result of dust and gases spreading in the soils, the content of trace elements increases, the soil and micro flora reactions change, soil compaction changes, and therefore aeration deteriorates. As a result, the structure and chemical composition of soils change.

To date, in Lugansk region, the number of mines, including closed mines and mines under private ownership, is more than 300. To this one must add about 30 concentrating factories since the latter play the same role in reducing the land stock.

Mining operations within Lugansk region cover an area of over 1,300 km^2, mainly on the right bank of the Seversky Donets. The area of mines exceeds 8,000 km^2, which accounts for 31 % of the area of coal in the region (Taliev, 1896).

The urgent problem of the coal district in Lugansk region has long been the physical loss of land, that is, the reduction of land resources due to their occupation by dumps of rocks and industrial land structures and communications, which make up more than 4 % of the area of the coal region. Annually in the dumps of mines and concentrating factories 12 million tons of «empty» rocks are accumulated. The total volume of excavated rocks on the surface within Lugansk region is more than 10 billion cubic meters (Taliev, 1896).

For several centuries, large areas under agricultural and forest lands have been destroyed or substantially reduced, and large areas have been involved in various man-made communications facilities. In Lugansk region, the mining industry alone has reduced the land fund of the region by 4,1 % (Bucik, 1993).

The change in the structure of land indirectly affects the general state of the environment. Thus, during the extraction and enrichment of coal, solid, liquid and gaseous wastes are formed, which constantly replenish the waste heaps, tailing ponds, pollute the atmospheric air, ground water, and the soil itself.

According to the state regional exploration enterprise «East-DRGP», the volume of dumps and heaps increases annually by 1.5 million m^3. The total area occupied by the rock mass, concentrated on the surface, is 25.834 km^2. The area of influence of dumps and heaps is more than 175 km, or 0.7 % of the area of the region and 2 % of the area of the coal region and 7 times the areas occupied by these artificial formations. The total area affected by mining operations exceeds 30 % of the area of the coal district of Lugansk region (Taliev, 1896).

Conclusions. Literary and archival material provide evidence that the problems of the catastrophic state of the land fund of the Lugansk oblast, in particular agricultural land, have not only failed to diminish, but have deepened over time.

Both intensive and extensive agricultural activity in Lugansk has for centuries led to degradation of land in agriculture due to accelerated anthropogenic erosion, and in mining - due to physical extraction of land due to intensive mine construction and toxicification of soils with mine waters and wastewater from mining rock.

Land use patterns have become damaging features; the use of land in the region has become inefficient and ineffective, and requires the development of new conceptual principles and a systematic approach to the formation of an optimal structure of nature use in general and land use in particular.

In our opinion, the structure of land use should be shaped according to the peculiarities of the natural conditions, in particular, those mentioned above. And this, first of all, must take into account the presence and predominance of slopes, which are erosionally dangerous, and therefore this factor should logically regulate the size of the areas of different types of land.

We are convinced that the current structure of land use in Lugansk region is determined both by natural factors and by the peculiarities and stage of economic development of the region. The inappropriate attitude to natural resources, in particular land, has led to irreversible degradation processes, which makes Lugansk region one of the most ecologically problematic regions of Ukraine.

In developing the strategy of optimal nature management for the IIIrd millennium, one must take into account the whole complex of factors - from natural to economic, social and environmental at the state level. Only then will it be possible to move the whole of Ukraine, each of its regions , to sustainable development. For Lugansk region, as well as for Donetsk, synonymous with the tragic events associated with the antiterrorist operation, and now world famous under the name «Donbass», the problem of optimization of land use, restoration of its structure on new conceptual basis is a matter of the greatest urgency.

One of the ways out of the current situation, in addition to monitoring the land currently in use, is in our opinion an immediate revision, diagnosis, soil evaluation, and reclamation of the entire land fund of the region, which requires the use of new techniques, environmentally modern technologies, developed specifically for the specific natural and socio-economic conditions of Lugansk region.

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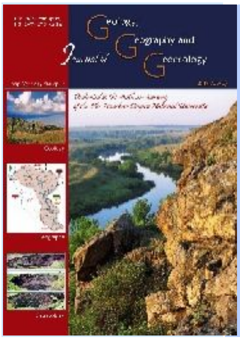

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Environmental risks and assessment of the hydrodynamic situation in the mines of Donetsk and Lugansk regions of Ukraine

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Abstract. Modern environmental risks and threats relate with the negative impact of anthropogenic and natural factors on ecosystems, man-caused negative impact of industrial and potentially hazardous objects, pollution of drinking water sources, agricultural land, atmospheric air, deviation of the geological environment and subsoil on the safety of life in certain areas. Coal enterprises are one of the objects of high ecological danger and critical infrastructure. Today, environmental safety in the east of Ukraine should be considered in close connection with the ecological and man-made threats associated with combat operations in these territories. The authors carried out an analysis of scientific researches of past years and provided an assessment of environmental risks in the territories of coal mining enterprises in the present conditions considering the structural-geological, geofiltration and mining-geological parameters typically for the Donetsk and Luhansk regions of Ukraine. The article considers the location of mines in Donetsk and Lugansk regions as zones of high ecological danger. The existing ecological threats and risks are determined, recommendations for minimization threats and risks in case of anthropogenic and environmental disasters are provided. The equation of calculating the coefficient of filtration in rocks is made, mineral-technical parameters of coal mines are analyzed. It is shown that one of the most probable factors of the transition of the territory into a zone of an emergency situation of a regional scale is the emergence of real threats to the life of a large number of people in the conditions of mass flooding of mines due to the termination of power supply of drainage and ventilation systems. Also in the article scientifically substantiated the provision of an acceptable level of environmental safety of the constituent parts of the environment (water environment) for the population living within the mining and agglomeration, taking into account the environmental factors of the negative factor-forming factors, as well as forecasting the hydrodynamic situation.

Key words:*ecological safety, threats and risks, mine waters, hydrodynamic situation, groundwater, coefficient of filtration, flooding of the territory.*

Екологічні ризики та оцінка гідродинамічної ситуації на шахтах Донецької та Луганської областей України

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Анотація.Сучасні екологічні ризики та загрози стосуються негативного впливу антропогенних та природних чинників на екосистеми, техногенні – негативного впливу промислових та потенційно небезпечних об'єктів, забруднення джерел питної води, сільськогосподарських земель, атмосферного повітря, вплив геологічного середовища та надр на безпеку життєдіяльності на визначених територіях. Вугільні підприємства є одним із об'єктів підвищеної екологічної небезпеки та критичної інфраструктури. Сьогодні екологічну безпеку на Сході України треба розглядати в тісному зв'язку з еколого-техногенними загрозами, що пов'язані з бойовими діями на цих територіях. Автори здійснили аналіз наукових досліджень минулих років та надали оцінку екологічних ризиків на територіях вуглевидобувних підприємств в сучасних умовах врахувавши структурно-геологічні, геофільтраційні та гірничо-геологічні параметри, що є характерними для Донецької та Луганської областей України. В статті розглянуті території розміщення шахт Донецької та Луганської областей як зон підвищеної екологічної небезпеки. Визначено наявні екологічні загрози та ризики, надано рекомендації щодо їх мінімізації у разі виникнення техногенно-екологічних катастроф. Складено рівняння розрахунку коефіцієнта фільтрації у гірських породах, проаналізовано гірничо-технічні параметри вугільних шахт. Показано, що одним із найбільш ймовірних факторів переходу території в зону надзвичайної ситуації регіонального масштабу є виникнення реальної загрози життю великої кількості людей в умовах масового затоплення шахт через припинення енергопостачання водовідливних та вентиляційних комплексів. Також в статті науково обґрунтовано забезпечення прийнятного рівня екологічної безпеки складових навколишнього природного середовища (водного середовища) для населення, які мешкають в межах гірничо-міських агломерацій з урахуванням впливу на довкілля негативних фактороформуючих чинників, а також прогнозування гідродинамічної ситуації.

Ключові слова: *екологічна безпека, загрози та ризики, шахтні води, гідродинамічна ситуація, грунтові води, коефіцієнт фільтрації, підтоплення території.*

Introduction. Coal enterprises are one of the critical infrastructure objects (CIO) and high ecological danger objects and located both in the controlled and temporarily occupied territory.

It should be noted that on a controlled territory local authorities have the opportunity to monitor the state of the environment and control the development of events associated with the operation of these objects, which in turn enables the taking of measures to prevent emergencies, and in case of occurrence of such situations, to quickly locate and eliminate them. At the same time, central executive authorities and local self-government bodies do not known the state of the CIO located in the temporarily occupied territories of Donetsk and Luhansk regions. Due to this, the situation regarding their further safe functioning is not predictable.

Because of the hostilities, the threat of damage to such objects is quite large. Therefore, in case of an accident, the localization and elimination of the consequences of such a situation may be complicated due to the inability to access the places of damage. As an example, the mines of the Central region of Donbas.

Materials and methods. The analysis of the filtration model of mines flooding is considered with the scheme of the critical level of flooding of the produced space and the calculation of the filling factor (K_f). Due to the active development in the zone of influence of coal-mining works of technogenic fracture, the aquifers, which water the mines, are dispersed, form three-dimensional geofiltration fields with a complex structure. As a result, each separate mine during flooding creates its own geofiltration field and the local water balance of the auto-rehabilitation rise of the groundwater level to natural (retro-historical) markings.

Autoreboiling mode of raising the levels in the process of flooding the mine from its maximum depth to the zone of regional permeability is ensured due to a significant excess of the area of depression over the generalized size (“large well”) of mining production in the plan. In this regard, the structure of the graphoanalytic dependencies of the time tracking of the rise of levels during flooding of the mines (for example, the Gorlivka-Yenakiyevo mining and city agglomeration of the Donbas, the Central District of Donbas) mainly reflects the influence of the hydrodynamic potential of the depression reservoir outside the generalized drainage path of mining operations (Shestopalov V., 1991).

The authors carried out an analysis of scientific researches of the last years and tried to assess the ecological and geological risks in the territories of coal mining enterprises in the present conditions taking into account structural geological, geofiltration and mining-geological parameters that are characteristic of the Gorlivka-Yenakiyevo mining and city agglomeration (Sadovenko I., 1999).

It should be noted that the problems of the environmental consequences of military operations, attention was paid only relatively recently. Internationally, the environmental impact of conflicts in the former Yugoslavia, Afghanistan and the Middle East, conducted by the United Nations Environment Program (UNEP), is well known internationally. In 2006, the OSCE and UNEP assessed the spread of grass fires in Nagorno-Karabakh, and in 2008, the environmental consequences of the military conflict in Georgia. Today, various intergovernmental and non-governmental organizations are taking part in assessing the environmental impact of hostilities in Syria and Iraq.

All organizations that prior to the conflict gathered information on the state of the environment in the Donetsk and Luhansk regions, suffered violations in their work, most of them lost their equipment, technical, material and transportation support, archives and documentation. The volume of reporting to the state statistics bodies has been reduced. At the same time, from the beginning of 2015, the Ministry of Ecology and Natural Resources of Ukraine, on the basis of available information, is preparing monthly informational and analytical certificates on the state of the environment in eastern Ukraine. Information on the humanitarian situation in settlements, as well as cases of violations of water, gas and electricity is contained in the daily summary data of the Information and Analytical Center of the National Security and Defense Council of Ukraine. An analysis of the situation in the conflict zone in the east of Ukraine is carried out for a limited set of sources (Rudko G., 2016).

Today, on parts of the territory environmental monitoring is not carried out, there is no reliable information about the nature of enterprise damage, the secrecy regime is in place, and the work of the State Environmental Inspectorates in the Donetsk and Luhansk regions is complicated. But in 2017, at the request of the Ministry of Ecology and Natural Resources of Ukraine, the OSCE Project Co-ordinator in Ukraine conducted a project "Determination of damage to the environment in eastern Ukraine", whose tasks were to conduct an analysis of the environmental impact of the conflict and to prepare recommendations for the prospective recovery of the region. The project was supported by the Government of Canada and Austria (Denisov N., 2017).

The main body. The flooding of mines, and the subsequent occurrence of areas flooded areas, is the main thing that will occur as a result of non-power and damage to the equipment of enterprises of the coal mining industry, as well as one of the main causes of potential pollution of underground and surface water when they contact with mine waters. A particular threat is flooding of mines used as waste storage facilities.Such a danger, first of all, exists for the mines "Oleksandr-Zakhid", "Vuglegirska" and Kalinina in Gorlivka, Donetsk region. Radiation pollution of groundwater can cause flooding of the mine "Yunyy Comunar", where an underground nuclear explosion (object "Klivazh") was carried out in 1979 as part of the experiment to reduce the tension in the rock massif to improve the safety of the development of the coal seams of the Smolyanov's world (C_2^3).It should be emphasized that in stable conditions and at the fulfillment of technological requirements for conservation, the risk of radioactive contamination beyond the boundaries of the Mining System "Yunyy Comunar – Klivaz" is practically absent, but with destabilization of the system and the absence of additional measures, it is possible to destroy this facility with the release of radioactive contaminated mine water in underground aquifers (up to 300 m^3/hour) (Rudko G., 2016).

Fig. 1. Mine "Oleksandr-Zakhid"

As a result, buildings and structures of CIO, such as water supply networks, underground gas pipelines, sewage systems and water supply systems, may be damaged. In addition, flooding of the mine will lead to pollution of underground and surface water by iron, chlorides, sulfates, other mineral salts and heavy metals.

Mine "Oleksandr-Zakhid" located in Gorlivka, Donetsk region on temporarily occupied territory. Since 2001, it is in the process of liquidation. The depth of development is 450 m, the water intake is 220 m^3/hour.The discharge of mine water is carried out in the basin of the rivers Poklonska - Sadky - Krynka - Azov Sea.

Ecological threats: after the accident in 1989, the mine was transferred to a conservation mode, and since 2001 it has been transferred to the drainage regime under the project of liquidation. In 2017, the pumping of water on the 250 m horizon was stopped. Subsequent large-scale flooding of the mine may lead to flooding of surrounding areas, affect the level of groundwater, cause soil subsidence (Bondar O., 2017, Lysychenko G., 2014)

Fig. 2. Mine "Yunkom"

Mine "Yunkom" located in Yenakievo, Donetsk region on temporarily occupied territory. Since 2001, it is in the process of liquidation. The depth of development is 936 m, the water intake is 420 m^3/hour.The discharge of mine water is carried out in the basin of the rivers Millionna - Bulavinka.

Ecological threats: After the discontinuation of coal mining in 2001, it was transferred to the drainage regime under the project of liquidation (flooded to the level - absolute mark -735 m). Flooding of mining productions can lead to the accumulation of radionuclides in groundwater with the possible hydraulic displacement of them on the surface or in the flow of groundwater. (Bondar O., 2017).

Environmental threats of location of the mine also include flooding of the surface, contamination of aquifers by mine water with high mineralization, methane gas output to the surface and its entry into the building and facilities, forming within the boundaries of the Gorlivka-Yenakiyevo industrial zone a dangerous man-made hydrogeofiltration system, it unites hydraulically connected mines of the region.

The leading methodological position is to determine the rate of lifting of groundwater levels to dangerous depths and the time of flooding of the mine as the main integral parameters for the probable forecasting of environmental impacts and the justification of effective engineering protection measures (Hydrogeology, 1971).

On the basis of the calculated difference of headings, in accordance with the position of the mirror of underground water carbon and hypsometry of the earth's surface, the possible yield of mine water to the surface of the earth at the site is assessed in the case of full flooding of mine productions. The equation of the calculation of the filtration coefficient in the rocks is made, the mining and technical parameters of the coal mines of the northern and southern wings of the central region of the Donbas (main anticline) are analyzed, flood levels of mine productions of the mines of the region are recorded, which testify to the formation of a complex man-caused geofiltration system in the zone of impact of mine dewatering, within which the following processes prevail:

- flooding of mining productions and watering of the adjoining massif of rocks with the rise of groundwater levels and reduction of their depression;
- additional shifts and sinking of rocks;
- change of the ways of migration of explosive and toxic gases (methane, radon, etc.), including towards existing mines, tectonic zones, underground spaces and reliefs;
- the dispersal of the migration of mineral waters of the deep horizons within the mine fields with their subsequent inflow into the local underground and surface runoff.

In order to take into account the influence of the basic balance parameters of mining operations (Babushkin V., 1972) (the cross-section of mine workings $F_{ш,t}$ and active porosity or lack of water saturation), the following modification of the dependence of the Dyupui radial flow, which takes into account the time changes of the influx, $Q_{ш,t}$,. on the speed of lifting levels , ds_t / dt is used:

$$Q_{ш,t} \approx F_{ш,t} \times \mu^{ds}/dt \approx \frac{2\pi k m S_t}{\ln^R/r_ш},$$

where, $Q_{ш,t}$ – water flow to the mine at time t when the groundwater level decreases S_t m^3/day; $F_{ш,t}$ – free section of mine productions and the zone of artificial fracturing of broken rocks on the horizontal markings corresponding to S_t, m^2; R – the radius of depression of groundwater, m; $r_ш$ - conditional radius of the planned contour of mining productions and zone of breakage (artificial fracturing),m; - km - permeability of coal-rocks in natural or slightly degraded state, m^2/day;

- μ - the average value of active porosity (lack of water saturation) of coal-bearing rocks in the recovery zone of groundwater levels (in units).

The natural hydrodynamic situation of the Central district of Donbas is disturbed as a result of coal mining. The bottom depth of the mining works is within the limits of 740-1160 m and only on separate mines (“Oleksandr-Zakhid”, “Pivdenna”) - 360-450 m.

Two thirds of the mining area has already been tampered with mining operations. The amount of water inflows in the mines of the region about 150-300 m^3/hour, and only at the mine “Chervonyy Zhovten”, the mining of which crosses the river Bulavin, reaches 820-890 m^3/hour (Sadovenko I., 1999). Modules of mine water jets on 1 km^2 of the mine shafts range from 2.9-25.3 l/s*km^2.

The most powerful bundles of dranaige rocks are fixed between the coal seams h_1, h_3, h_{10}i h_{11}, k_7, $k_7^{1в}$, k_5^1-$k_7^{1в}$, l_1, l_3-l_5, m_5^1-m_4^4, also in the zone of seams h_4-h_5, k_1-k_3, m_2-m_3, m_6^2.

According to some estimates, during the conflict, the total annual drainage in the Donbas decreased from 800 to 400-450 million cubic meters (Ermakov V., 2017). With the preservation of this trend in a few years, part of the mine water will begin to fall into the underground aquifers, mixing with groundwater.

In the thickness of the carbon there are about 100 layers of sandstones, which form dispersed, almost independent pressure aquifers, sustained in length and constant power. The zones of the supply of underground waters of the regional cracked zone of carbon in the natural and weakly disturbed conditions are confined to the watersheds, are discharged into the valleys of the nearest rivers and beams. In the greater part of the territory, due to the hydrogeological openness of carbon and the active technogenic cracking of rocks, precipitation infiltration takes on the nature of infiltration. In the areas of river crevices mining by means of underground and surface waters a close hydraulic connection is established.

The result of the complex influence of man-made factors (increased infiltration of mineralized mine waters, geochemical contamination of landscapes, violation of regional watercourses, etc.)

became almost complete replacement of fresh (up to 1.0-1.5 g/dm^3) and weakly mineralized (1.5-3, 0 g/dm^3) water for water with mineralization 3.0-5.0 g/dm^3 at 70% of the investigated areas. In modern conditions, due to the sharp difference in the permeability and volume of infiltration feed of cover and coal deposits in the limits of the Gorlivka-Yenakiyevo mining and city agglomeration of the Donbas, the Central District of Donbas, two tiered structure of the hydrogeofiltration flow was formed. It should be construed that flooding of mines with subsequent raising of groundwater level and decreasing depression will increase the depth of groundwater supply, flood and flood processes, as well as water saturation and decrease of the strength of lower horizons of rocks with the manifestation of high-gradient sediments and breeds of continuity of rocks will increase. According to the results of modeling, on the 50% of the area of the Gorlivka-Yenakiyevo mining and city agglomeration of the Donbas, the forecast depth of groundwater levels of the coal-bearing horizon is 20.0 m or less, as a result of which this area is capable of local flooding of hot spots, development available and formation of new centers of pollution of groundwater (Temporary methodical recommendations, 2001).

Almost all of the mines in the Gorlivka-Yenakiyevo mining and city agglomeration of the Donbas, located on the Southern and Northern wings of the Main Anticline, are hydraulically interconnected in the range of depths of 230-1080 m (Fig. 3 and 4).

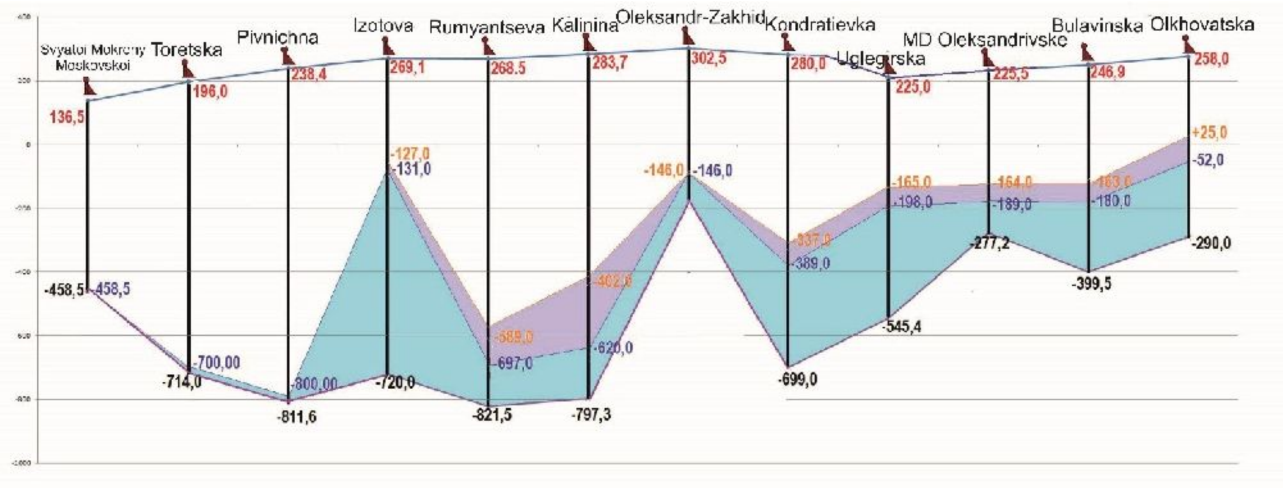

Fig. 3. Schematic section of the northern wing of the central region of Donbas (main anticline) on 01.06.2018

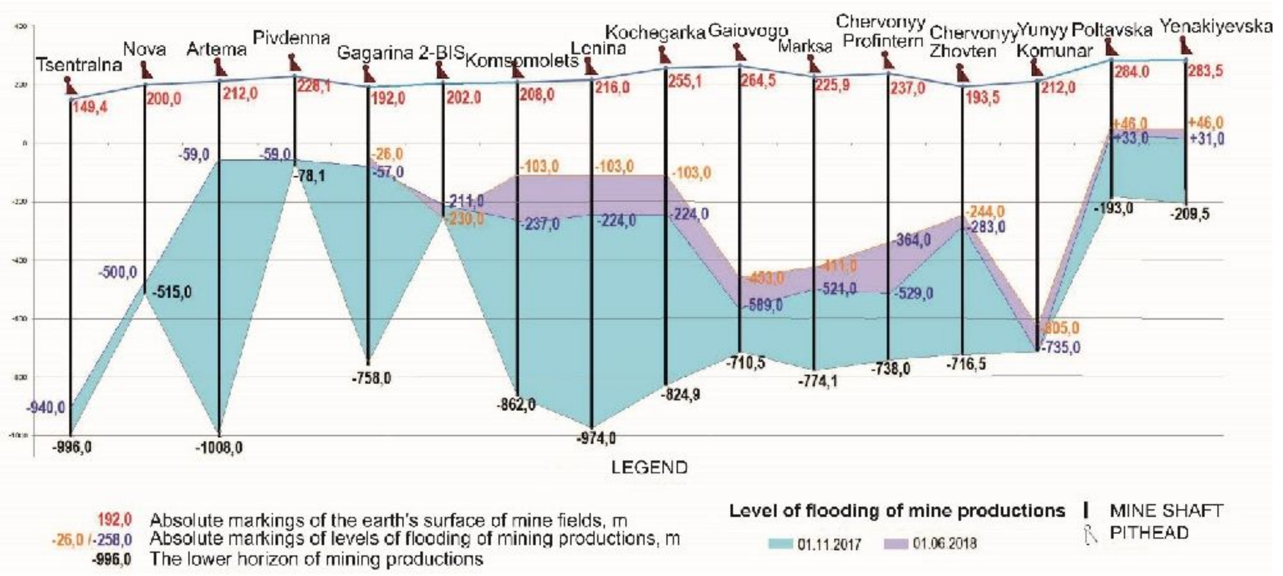

Fig. 4. Schematic section of the southern wing of the central region of Donbas (main anticline) on 01.06.2018

The analysis of the structural and geological structure and hydrogeological conditions of the mines of the Central District of Donbas has shown that they, in conjunction with the technological geological system “mine-geological environment” form a single hydraulically-geofiltration system with a high level of technogenic vulnerability of groundwater.

According to the available data (Yermakov V., 2017), the total number of direct hydraulic faults in these mines is about 14, and the approximate mining (for the standard reduction of intermontane shafts) - up to 10 zones with a total length of ~ 1.5-2.0 km. The distribution of abnormal mines in practically all depths (0.2-0.9 km), in our opinion, can lead to activation of hydrogeomechanical deformations of the rock mass as a result of decreasing the rock strength through full or partial flooding of workings, as well as the formation of additional ways of accelerating migration of pollutants, explosive and toxic gases.

In the case of partial or full flooding of mines in the Gorlivka-Yenakiyevo mining and city agglomeration of the Donbas, without the prior application of engineering and protective and environmental measures, damage to the waterproofing of waste storage facilities, catastrophic contamination in mining operations, groundwater horizons and surface water streams may occur. Violation of the current equilibrium state of the technological geological system an industrial source of pollution -the geological environment can lead to the creation of an emergency ecological situation in this region. Volynetske and Olkhovatska reservoirs are in the territory of the Donetsk region under the threat of pollution; and the flooding of the Torez-Snizhne group mines can lead to the pollution of the Grabiv reservoir. All of these reservoirs are reserve sources for economic use.

Fig.5 Mine “Zolote”

Mine “Zolote” is located in Zolote, Popasna district of the Lugansk region. Put into operation in 1943. The design capacity is 650 thousand tons of coal per year, actual - 300 thousand tons. The mine field is uncovered by three vertical trunks, 2 - up to the horizon of 600 m, 1 - up to the horizon 865 m and the sloped shaft. For the June 1, 2018, the water flow in mining productions is 260 m^3/hour. The discharge of mine water is carried out in the basins of the rivers Kamyshuvakha and Siversky Donets.

Ecological threats: in case of flooding of mining productions of the mine “Zolote” (to the absolute mark of the supposed overflow of water -163 m), mine water will fall on the working mines “Carbonit” and “Girska”, which may lead to the discharging of highly mineralized contaminated mine water in the reservoir and small rivers, with possible water pollution in the wells of individual water use and in large water intakes, which provide drinking water all the Pervomaysk-Stakhanovsk region. (Shmandiy V.,

Fig. 6 Mine “Pervomayska”

Mine “Pervomayska” is located in Pervomaysk, Lugansk region, on the temporarily occupied territory. Since 2005 is in the process of liquidation. The depth of development was 720 m, the water flow was 325 m^3/hour. Mining productions are flooded.

Ecological threats: due to the accident December 2, 2015, the mine “Pervomayska” began flooding (flooded level - absolute mark - 156 m). The volume of water flow is 360 m^3/hour. The speed of raising the water level in the vertical shaft of the mine “Pervomayska” is 0.2 m/day. The expected flow of mine water towards the operating mine “Zolote” (due to the mining productions of the mine “Rodina”) will occur at an absolute value of -162.6 m.

In case of reaching the overflow horizon (absolute marking -162 m) and the flow of water to the mine “Zolote”, the total additional volume of water from the two mines “Pervomayska” and “Golubivska” will be about 1060 m^3/hour. In general, the volume of water flow at the mine “Zolote” will be about 1500 m^3/hour. It is also possible to flood the Stakhanov-Bryanka region, closed mines of the Kirov group.

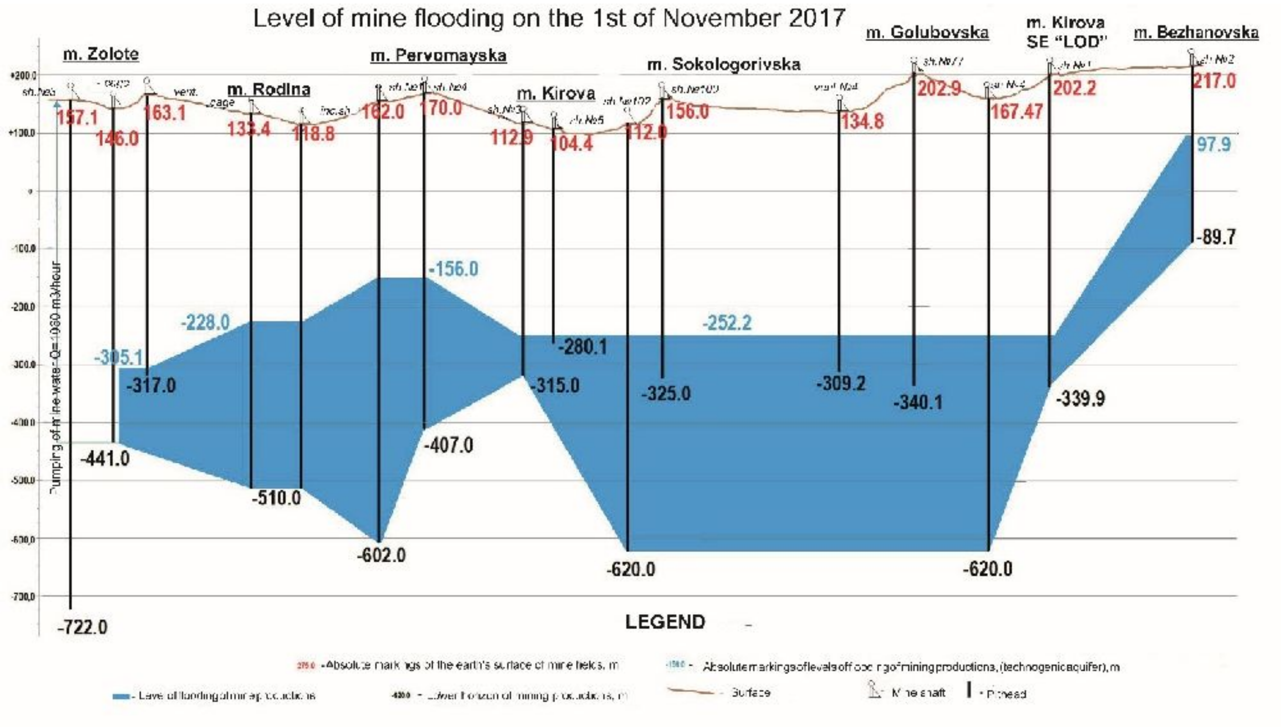

Fig. 7 Schematic section of Pervomayska group of mines of Lugansk region

The operating mine “Zolote” and the mines “Pervomayska” and “Golubivska” are hydrogeologically interconnected. At the same time, mine waters flow from the mines “Golubivs'ka”, “Pervomayska”, in which, as a result of combat operations, the pumping of mine water was stopped, due to the productions of the mine “Rodina” on “Zolote”, and then on the mine “Carbonit” and “Girska”.

The flooding of the mining productions of the “Zolote” mine can lead to the following negative environmental consequences:

• discharges of highly mineralized contaminated mine water into the reservoir and small rivers, while the wells of individual water use and large water intakes can fail;

• changes in the physical and mechanical properties of the rocky rocks and the resulting additional shifts, and, consequently, the formation of cavities on the surface of the caverns in the underground space;

• collapse of the mouths of trunks, mining workings, having access to the surface and the adjoining earth’s surface with possible flooding;

• occurrence of uncontrolled release of mine gases, in particular methane, on the surface;

• violation of the conditions for the normal functioning of mining towns and settlements, which at the time of closure of mines were already repeatedly forged by mining;

• activation of the deformation of the rock, due to their rinsing when flooding the mines, which can cause additional damage to buildings and structures.

Conclusions and recommendations for minimizing risks.

For the group of mines “Zolote”, “Pervomayska”, “Golubivska”.

In order to minimize risks, it is essential to strengthen the drainage complex of the “Zolote” mine. The optimal solution is to build a group drainage at the mine “Zolote” with a capacity of 1366-1500 m^3/year.

It is also necessary to carry out:

- measures for the prevention of pollution and depletion of underground and surface waters;

- mechanical clearing and degassing of mine sewage;

- clearing underground drains;

- production control of the composition and properties of sewage, their influence on the state of surface waters;

- radiological examination of the territory;

- prevention of spontaneous combustion of rock mass in dumps;

- measures to prevent the development of dangerous geological processes (karst, landslides, subsidence, flood, etc.);

- if possible, to resume pumping of mine water in the mines “Golubivska” and “Pervomayska”.

For the mine “Oleksandr-Zakhid”

- it is necessary to monitor the migration processes of explosive and highly toxic gases and compounds;

- it is necessary to develop measures for the prevention of pollution and depletion of underground and surface waters, the development of dangerous geological processes (karst, landslides, subsidence, flooding, etc.);

- if possible, resume pumping of mine water into the mine.

For the mine “Yunkom”

- conduct a comprehensive radioecological survey of the mine “Yunkom” and its zone of influence in order to identify areas of accumulation, ways of distribution and migration of groundwater (with dangerous solutions present in them) that rise to the surface during uncontrolled flooding of the mine;

- to create a monitoring system on the level of raising and distribution of water supplies to adjacent mining and industrial objects, non-industrial objects and the environment;

- on the basis of the evaluations carried out and according to the obtained data, to carry out the classification of the object “Klivazh” in accordance with the requirements of the regulatory framework in the field of radioactive waste management and radiation safety;

- taking into account the above and in order to prevent the contaminated water from entering the general water supply system, take urgent measures to ensure an adequate level of safety at the mine “Yunkom” and in the area of migration of polluted waters in the area of the mine location.

- development of measures to prevent pollution and depletion of underground and surface waters, development of dangerous geological processes (karst, landslides, subsidence of the surface, flooding, etc.).

Thus, one of the most probable factors of the transition of the territory of Donetsk and Lugansk regions to the state of emergency on a transboundary scale is the risk of massive uncontrolled flooding of the mines due to the cessation of the supply of drainage and ventilation systems. The consequences of rising groundwater to the surface may be the flooding of large areas of adjacent cities and towns, subsidence of the earth's surface in built-up areas, pollution of surface and underground water intakes. In addition, there is a risk of methane migration to basements, ravines, gullies and basins, which will increase the risk of explosions and fires.

Given the impossibility of verifying and carrying out a comprehensive analysis of the hydrogeological state of the mines in the Donetsk and Luhansk regions of Ukraine due to their location on the uncontrolled territory by the Ukrainian authorities, we consider it expedient to work out the issue raised during the meeting of the Tripartite Contact Group in Minsk on the settlement of the situation in the Donbas for discussion with representatives of certain districts of the Donetsk region, where the mines are located, to take appropriate response and protection measures.

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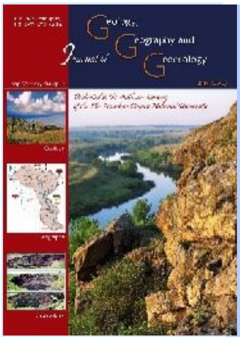

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Organization of tourist and recreational activity within the objects of the natural protected fund in the Odessa region

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Abstract. The article deals with the issues of nature use in protected areas, the exploitation of objects of the nature reserve fund for recreational and tourist purposes. It is emphasized that ecotourism, which includes, first of all, orientation of tourists to the consumption of ecological resources – recreational aspect, preservation of the environment – nature protection, is an important direction of recreation within the territories of the nature reserve fund, support of the traditional way of life of the local population – social aspect. The purpose of the work is to find out the features of the present state, to determine the problems and perspectives of the organization of recreation within the natural reserve areas of the state level in the Odessa region. Recreational and tourist attraction of the region for visitors are not only a wonderful climate and water resources but also available on territory of the region objects of the nature reserve fund, among which there are 16 objects of national importance. According to the recommendation of the International Union of Conservation of Nature and Ukrainian legislation, most of the categories of objects of the nature reserve fund provide for tourist and recreational activities within their territories in specially designated areas. Thus, the Danube Biosphere Reserve and two national natural parks, «Nizhnednistrovsky» and «Tuzlovsky Limany», joined the tourists for both short–term and long–term recreation. With the purpose of ecological education, the abovementioned objects of the nature reserve fund of national importance are used to create ecological trails and organize tourist routes. Thus, the most popular water tours in the Danube Delta to the mouth of the river with a visit to the symbolic «0 km» of the Danube, as well as tours for the observation of birds. On the river Dniester are popular sport fishing trips, as well as landscape tours. On the relatively untouched coast of the Black Sea, including the territory of the national park «Tuzlovsky Limany» lies one of the most interesting and cognitive routes of the Odessa region, which includes elements of ecological, rural, ethnic and extreme tourism. It is established that at the present time, organizational and recreational activities within the protected areas of Ukraine, as well as the Odessa region are at the stage of formation, the result of which is that its economic efficiency is extremely low.

Key words:recreation, ecotourism, nature reserve fund, national natural park, biosphere reserve, biotic diversity.

Організація туристично–рекреаційної діяльності в межах об’єктів природно–заповідного фонду в Одеській області

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Анотація. В статті розглянуто питання природокористування на природоохоронних територіях, а саме використання об’єктів природно–заповідного фонду в рекреаційних та туристичних цілях. Наголошено, що важливим напрямком рекреації в межах територій природно–заповідного фонду є екотуризм, який об’єднує всі ті види туризму, що орієнтовані на довготривале збереження природного довкілля (зокрема, заповідних ландшафтів), формування інтелектуально–гуманістичного світогляду, налагодження гуманних стосунків з місцевим населенням та органами самоврядування, поліпшення фінансово–економічного благополуччя віддалених регіонів. Розглянуто особливості організації туристично–рекреаційної діяльності в межах Дунайського біосферного заповідника, Нижньодністровського національного парку та національного парку «Тузловські лимани». Встановлено, організаційно–рекреаційна діяльність в межах природно–заповідних територій, як України, так і

Одеської області знаходиться на стадії становлення, результатом чого є те, що її економічна ефективність надзвичайно низька.

Ключові слова: рекреація, екотуризм, природно–заповідний фонд, національний природний парк, біосферний заповідник, біотичне різноманіття.

Introduction. In the Odessa region, unique natural complexes and ecosystems, highly valued wetlands of international importance are concentrated in the territory of which a large number of rare and endangered species of plants, mammals and birds are registered, which determines the development of ecological tourism in the region. Ecotourism is a trip to places of relatively untouched nature that do not lead to a violation of the integrity of ecosystems in order to get an idea of the natural and cultural and ethnographic features of this territory, which creates such economic conditions, when nature protection becomes beneficial to the local population, which subsequently becomes conscious, that nature is the main value of the territory and the source of their own profits. Recreational and tourist attraction of the region for visitors, in addition to the natural conditions (water objects, climate, scenic landscapes, diversity of flora and fauna, etc.), also make available on its territory objects of the nature reserve fund. **The purpose of the work** is to find out the features of the present state, to determine the problems and perspectives of the organization of recreation within the natural reserve areas of the state level in the Odessa region. Analysis of previous researches shows that various aspects of recreational and tourist activity in protected natural territories are covered in the works such authors as Boreyko V., Kotenko T., Mironova L., Stilmark F., Kekushev V., Sergeyeva T., Stepanitsky V., Lyubitseva O., Dmytruk O. and others. However, some issues remain controversial and require further study.

Data and methods. The materials of the study served as literary sources, as well as individual developments of modern domestic and foreign scientists on the study of recreation and tourism activities within the protected areas of the world. The cartographic method was used to assess the territorial peculiarities of the recreational activity organization in the Odessa region within the boundaries of nature–protected territories of national importance; The method of field research was used to gather material on the organization of recreational activities on the territory of the Danube Biosphere Reserve, Nizhnednistrovsky National Nature Park and the Tuzlovsky Limani National Nature Park.

Results of the study and their discussion. By definition of The International Union for the Conservation of Nature (IUCN) the nature protection (nature reserve) area is «a land and / or sea area specifically designated for the conservation of biodiversity, natural and related cultural resources, an environmental protection regime, within which it is provided by legislative and other effective means». Since 1992, IUCN has identified six categories of protected areas (Lausche, 2011). These categories are determined depending on the direction of the management objectives (Table 1).

As can be seen from Table 2, recreational activities are foreseen for practically all international categories of the organization of protected areas (except category I). Priority recreational activity is defined for categories II, III, V.

In Ukraine, all protected areas are united into the Nature Reserve Fund (NRF), which is divided into 11 categories, three of which are national natural parks (NNPs), natural and biosphere reserves – have a national status (Pro prirodno, 1992). The category «Biosphere Park» is included in the list of categories of the nature reserve fund of Ukraine – as an analogue of the international category «Biosphere Reserve» and combines the functions of biodiversity conservation and sustainable socio–economic development. Tourist and recreational activity in the territory of biosphere parks of Ukraine may be conducted within the zone of anthropogenic landscapes and an area of regulated reserve regime.

National nature parks of Ukraine perform the same functions and pursue the same management objectives as National Parks under category II of IUCN. At the same time, large areas of economic zones of Ukraine's NPPs show that they have elements of category V «Protected landscape / marine water», and the fact that each of the Ukrainian NPPs includes a protected zone allows us to speak about the presence of an element of the first category of IUCN here. Although, unlike natural reserves, according to Art. 21 of the Law of Ukraine «About the Nature Reserve Fund of Ukraine» (Zakon, 1992) in the national nature parks, in order to preserve nature, the implementation of health improvement, scientific and educational work, environmental education, in addition to protected areas and economic zones, it should be distinguished zones of regulated recreation and zone of stationary recreation. Within the regulated recreation zone, short–term rest and improvement of people are carried out also an overview of especially picturesque and memorable places.

Table 1. Categories of IUCN Natural Reserves (Dudley, 2008)

Index of categories		**Name**		**The features of management and protection**
		in english	*in ukrainian*	
category I		Strict Protection	Територія суворої охорони	–
	Ia	Strict Nature Reserve	Природний резерват суворої охорони	management is directed mainly to scientific research
	Iб	Wilderness Area	Територія для збереження дикої природи	Wildlife protection is carried out without interference with natural processes
category II		National Park	Національний парк	management for the conservation of ecosystems and for recreational purposes
category III		Natural Monument	Пам'ятка природи	management to protect specific natural features
category IV		Habitat/Species Management Area	Територія для збереження природних середовищ і видів	the protection of certain types of natural environments and / or certain species of flora and fauna or their groups is carried out
category V		Protected Landscape/Seascape	Територія охорони ландшафту / морська акваторія	combined with the preservation of landscapes and / or water areas and recreation
category VI		Managed Resource Protected Area	Територія охорони ресурсів	preservation of natural values is ensured through the sustainable use of natural resources

As we can be seen from the objectives of the management of the nature reserves of different categories of IUCN, these objectives coin-cide for many categories. However, they have a different degree of importance to them (priority). Table 2 gives an idea of these relationships.

Table 2. Objectives of the management of natural protected areas

Purpose of management	**IUCN Category**						
	Ia	Ib	II	III	IV	V	VI
Scientific research	1	3	2	2	2	2	3
Wildlife protection	2	1	2	3	3	–	2
Preservation of species and genetic diversity	1	2	1	1	1	2	1
Maintenance of ecological services	2	1	1	–	1	2	1
Protection of specific natural / cultural features	–	–	2	1	3	1	2
Tourism and recreation	–	2	1	1	3	1	3
Education	–	–	2	2	2	2	3
Sustainable use of natural ecosystem resources	–	3	3	–	2	2	1
Support for cultural / traditional values	–	–	–	–	–	1	2

Symbols: 1 – the main purpose, 2 – secondary purpose, 3 – potential purpose, – the goal is not put.

This area is equipped with ecological trails and tours are organized. In the zone of stationary recreation, there is a long rest, organized tourism, sanatorium and spa treatment.

The natural reserve fund of the Odessa region as of 01.01.2018 consists of 123 territories and objects with a total area of 159970,847 hectares. Of these, 16 objects of national importance with a total area of 112718.67 hectares and 107 local objects with an area of 47252.17 hectares (Perelik, 2018). Thus, the area of the natural reserve fund is 4.57% of the area of the Odessa region. At the same time, normative state documents provide for an increase in the share of reserves in Ukraine to 15% in 2020, and in the Odessa region – up to 10,4% – on January 1, 2021 year (Zakon, 2004, Zakon, 2010).

The author's team analyzed the territories suitable for the further formation of the ecological network within the administrative districts of the Odessa region (Javors'ka, Sych, Kolomijec', 2015). As a result of the study, the authors devised a mapping diagram showing areas with insufficient (0–25%), optimal (26–35%) and high (36–70%) of the areas that may be included in the regional eco–network (Figure 1), and therefore interested in ecotourists.

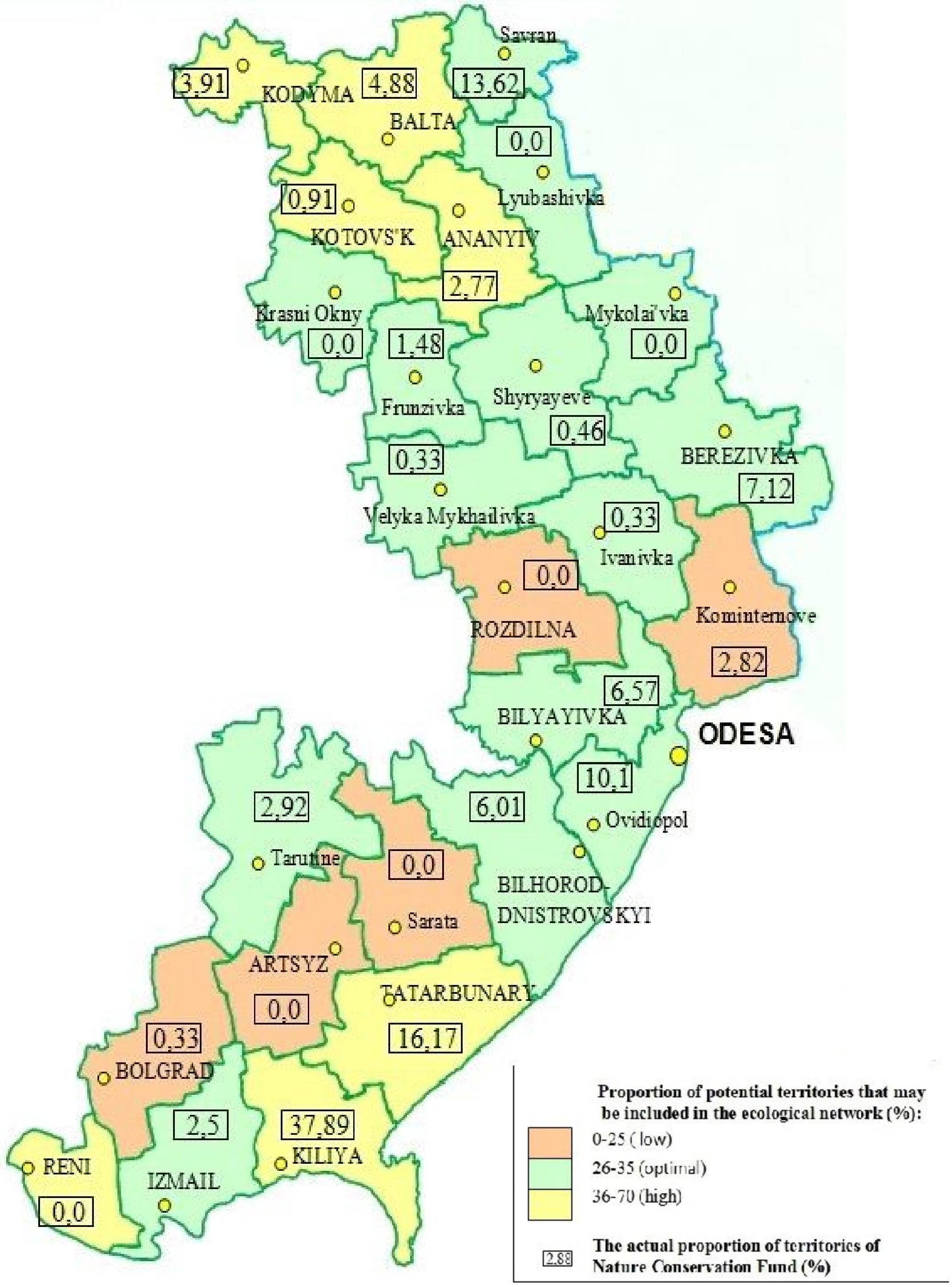

Fig. 1. Regional potential of the ecological network in the Odessa region and the actual area of the nature reserve fund (as of 2015)

An important issue is the reservation of territories for further granting them the status of the reserve. Yes, according to (Programa, 2005) in Odessa oblast the area of natural territories is worth to obtain reserve status are almost 80 thousand hectares. These include large massifs such as the Yalpug Lake, Kitay, and Kugurlui, as well as insignificant plot areas – slopes of river valleys, gullies, ravines where steppe vegetation is preserved. Again, without the regu-lated use of these territories today, then it will soon be possible to lose them altogether.

At present, the largest percentage of the reserve (the ratio of the area of the nature reserve fund to the total area of a certain territory) has areas, except Savransky belonging to the Seashore Zone, that is, they have access to the Black Sea – in Kilia 37.89% of the total area of the district, Tatarbunary 16.18% and Savran 13.62%. These areas are considered the most promising for the development of ecological tourism. There are no objects of the nature reserve fund in the Krasnoknyansky, Lyubashevsky, Reniysky and Saratsky districts.

Of the 123 objects of the Nature Reserve Fund, only 16 belong to state status objects, of which only 1 is represented by a biosphere re-serve (Danube Biosphere Reserve), and two are national parks (Nizhnednistrovsky and Tuzlovsky Limany National Nature Park). For recreational zones of the objects of the natural reserve fund of the Odessa Oblast, the possible types of ecological tours are presented in Table 3.

Table 3. Basic types of ecotourism

Types of tourist and recreational activities	Main goals
Scientific and educational tours and student practices	Geographic, ornithological, botanical, ichthyological, hydrological, ethnographic, birdwatching, photo and video tours
Passive recreation	Camping, picnics, walks, rural tourism, wellness tourism, boat trips, picking berries
Active recreation	Water tourism (kayaking, paddle–boarding), hiking, horseback riding, cycling tourism, diving
Business tourism	Trips to environmental conferences, symposiums, participation in environmental education work

Features of recreational activities within the Danube Biosphere Reserve. On the territory of Ukraine, the lower lands of the Danube are marked by their biological diversity. It is worth noting that the Kilia Delta, on which the Danube Biosphere Reserve is located, is the youngest creation of the river. Among all the large Mediterranean and Black Sea deltas, it has suffered the least from human activity. Today, the sea delta sleeves from the city of Vylkove to the confluence of the Black Sea are the most valuable part of the Reserve. Here dominate vast wetlands, represented by reed plumes, covered with a network of ducts, canals, with numerous lakes. In addition, there are diverse terrestrial ecosystems in the region. On a relatively small territory there are areas of floodplain forests, meadows, salt marshes, sands, remnants of the steppes. In densely populated and highly developed Europe, the Delta of the Danube is a real oasis of wildlife among the plowed and broken steppes of southern Ukraine, attracting numerous tourists. To ensure the protection of natural complexes in the Danube region, in accordance with the Decree of the President of Ukraine of August 10, 1998, No. 861/98, the Danube Bio-sphere Reserve was created on the basis of the Danube Plavni Nature Reserve.

The zones of the biosphere reserve included:

– marine delta of the Kilia arm of the Danube (below the city of Vylkove) – the reserve, buffer zone and zone of anthropogenic landscapes;

– Zhebryansky ridge – zone of anthropogenic landscapes;

– Stenzovo–Zhetrayanovsky floodplain – zone of regulated reserve regime;

– Ermakov Island – one of the largest islands in the Ukrainian Danube Delta – is 9.6 km long and 3.6 km wide; the area is about 2300 ha – the buffer zone and the zone of anthropogenic landscapes;

– the territory of the nearby non–operating fishery plant – is a zone of anthropogenic landscapes.

The structure of the institution corresponds to the decision of the main tasks, namely: the scientific department, the Department of protection and rational use of the nature reserve and the sector of environmental education and tourism operating. The legal field of the functioning of the Biosphere Reserve allows us to combine nature conservation with the rational use of natural resources. The practical implementation of the mechanism of rational and ecologically balanced use of the natural resource potential of the biosphere reserve is the provision of recreational services.

The development of ecological tourism and excursion activities for Biosphere Reserves is a very promising form of environmental propaganda, an effective means of forming a sense of pride and a desire to preserve the natural heritage in the population.

In its potential, the Danube Biosphere Reserve not only does not yield to other international reserves, but also has many advantages over them. An increasing interest in the reserve is observed not only by the international scientific community. He gains considerable popularity among domestic and foreign tourists, which requires paying special attention to such a type of tourism as ecological.

In order to attract tourists to take part in the nature protection of the region in various ways (scientific monitoring, projects for the restoration of degraded areas, financial assistance, etc.) and providing them with the necessary information, as well as their education, the Information and Tourist Center in the city of Vilkove was created. It is here that visitors are informed about the status of the protected area, measures that ensure the diversity of the animal and plant world, how to reduce the impact on vulnerable natural complexes and provide a lot of other useful information about the history of the land and nature use.

Ecological education of ecotourists is an opportunity to influence their behavior by increasing understanding of natural and cultural values, gaining unforgettable impressions by tourists. This is also a guarantee that the natural and cultural values that are very important for the locals will survive not only for the present generation, but for the descendants. Every year more than 3000 tourists visit the information and tourist center (more than 5,000 in 2015 and 2017 yy) – those who have chosen a place of rest and gaining new knowledge and pleasant impressions of the pearl of the Danube Region – the Danube Biosphere Reserve.

Tourist enterprises of the region have developed a number of various tourism programs for the promotion of ecological tourism, which were created on the basis of tourist and recreational potential of the regions of the Ukrainian Danube. Among the offered programs are day–to–day and multi–day excursions, photo tours, bird–watching tours, since in the Danube Biosphere Reserve 255 species of birds (62% in Ukraine) were identified, including 124 species, 196 flying nests. The Red Data Book of Ukraine includes 41 species: cormorant, white–tailed eagle, Pelican curly, Pelican pink, Black stork, Gaga ordinary, etc. The European Red List includes 7 species. Water conservation is also offered, 90 species of fish are registered in the reserve area, of which 15 are included in the Red Book of Ukraine (Sterlet, Danube Salmon, Black Sea Salmon, Atlantic Sturgeon, Umbra, Ruffle Striped, Beluga, etc.), and 7 in the European Red List. Also in the areas of regulated recreation for tourists is the possibility of swimming beach recreation. Due to the combination of sand dunes, pine forests, swamps and steppe vegetation on a relatively small area in the lower lands of the Danube, tourists can observe landscapes biodiversity.

The uniqueness of the Nizhnednistrovsky National Nature Park and its biotic diversity. The National Park is also widely used in the recreational activities of the region. Favorable climatic conditions of the lower land of the Dniester River, the presence of unique natural landscapes and biodiversity have created a recreational attraction and have become the basis for the creation of a national natural park on its territory. The appropriate conditions for creating a world–view, recreation and well–being of the population are created here.

An abundance of large and varied biotopes of the wetland complex, a developed network of natural, artificial, permanent and temporary delta rivers and reservoirs that feed the Dniester water territory of the Nizhnednistrovsky National Nature Park, pro-vide shelter and living space for more than 1500 species of representatives of the animal and plant world. In addition to natural and man–made biotopes of wetlands, one more type of natural habitats for the Lower Dniester basin should be noted – these are the small remains of steppe biocenoses on the floodplain terraces of the river and the Dniester estuary. Their total area is extremely small and does not exceed several hundred hectares. However, these lands are important as the habi-tats of a number of steppe species of small mammals and birds.

Determination of directions of recreational activities within the Nizhnednistrovsky National Nature Park was carried out in accordance with the requirements of the Order of the Ministry for Environmental Protection of Ukraine dated June 22, 2009 No. 330 «On Ap-proval of the Regulation on Recreational Activities within the Territories and Objects of the Nature Reserve Fund of Ukraine». Recreational activities are carried out in accordance with the zoning of the territory.

As of January 1, 2018, 4 ecological routes, length from 7 to 58 km and 1 ecological path were developed and approved in the Nizhnednistrovsky National Nature Park.

The *«Gontarenko Island»* ecological trail, length 3.5 km, runs through the island of Gontarenko, which is located on the right bank of the Dniester River, between the Oleksandrivsky and the Festival, near the village of Mayaki. The island, which passes the ecological trail, was named after the hydrologist and ecologist – Vadim Mikolayevich Gontarenko, who spent many years devoting his life to preserving the nature of the Dniester. During the tour, visitors will get acquainted with the natural complexes of the lower Dniester, typical representatives of flora and fauna, rich history of the region. Visit one of the last floodplain meadows, reedbeds and see the floodplain forest. Guests of the tracks learn about the difference between the reeds and deergrass, the great importance of these plants for the river ecosystem, how people have used them in their lives from time to time. See many medicinal plants and learn about their purpose and ways of using it. From the island there is an open landscape on the opposite bank of the river, where the village of Mayaki is located. The boat will deliver tourists to the last stop of the route, where they will be able from the observation tower on the shore of the Old Turunchchuk to see the entire Dniester estuary and the immense reed beds. The back road runs along the Aleksandrovsky Channel and along the Dniester to the village of Mayaki.

«Dnister Amazonia» – a river tourist route runs in the zone of regulated recreation along the Dniester River, the channel of Turunchchuk, the pic-turesque strait «Amazonka», introduces the mysterious and unique floodplain forest and a huge array of reed bed. On the route there is White Lake, which can be reached on the craft from the city of Bilyaivka and from the village of Mayaki. The length of the route from Bilyaivka – up to 8 km, from village Mayaky – 20 km. Duration of the route is from 3 to 6 hours. This ecological trail introduces tourists with the surrounding landscape and diversity of wet-lands, beautiful vegetable creatures – white lilies, yellow jugs and walnut. The tourists on the route constantly accompany the Aboriginal birds of the Dniester and Turunchuk rivers – swans, herons, gulls, etc.

«Kingdom of birds»– a water tourist route in the zone of regulated recreation, which starts from the village Mayaki, runs along the Dniester, then along the channel of the Deep Turunchuk with access to the Dniester estuary. Back – along the «Kiliary» Strait with the entrance to the Deep Turunchuk, and then along the Dniester to the village of Mayaky. The length of the route is about 20 km. Duration of the route is from 3 to 5 hours. On the route there are giant pelicans, graceful swans, numerous small and large cormorants, graceful herons, wailing marsh tusks, thickets of the most rare plants – fringed water lily (Nymphoides peltata), as well as the largest in Europe, the plantation of yellow water–lily (Nuphar lutea). The shallow areas of the estuary are attractive for summer swimming, both adults and children.

«Brilliant Ibis» car (bicycle, pedestrian) route, which passes through the economic zone and the zone of regulated recreation along the Mayaky – Palanka motorway. Its length is 10 km. Duration of the route is 3 to 4 hours. Among the many inhabitants of the delta can be called dozens of species that can give people the opportunity to assess the environmental situation in their presence or absence. However, the most interesting object is a brilliant bird or birdhouse. This graceful and sophisticated bird is the closest relative, probably known to many tourists, the sacred ibis, worshiped by ancient Egyptians. Korovayka is included in the Red Data Book of Ukraine. If the Dniester dam does not hold the water during the spring flood, it does not nest, or it has very little nesting. It breaks in reindeer thickets away from human eyes. You can watch these mysterious birds on flood plains during the flood period – in April – May.

«Yevsey's Trail» is an excellent pedestrian tourist route in the zone of regulated recreation on the slopes of the Dniester estuary. The length of the route is 5 km and the duration is from 3 to 5 hours. The trail passes through the steppe landscape and picturesque forest, formed by a tireless enthusiast – forestry Yevsey Pavlovich Kostetsky. This route will introduce the rare birds of the steppe zone and forest–steppe. In the shallow waters of the Dniester estuary there are numerous clumps (over a thousand specimens) of large cormorants, resting pelicans, and in the air the white–tailed eagle is steaming.

The uniqueness of the National Nature Park «Tuzlovsky Limany» and the organization of recreational activities within its borders. The Black Sea landscapes have suffered the most because of its great recreational attractiveness. As a result, in fact, in their natural form, there were only individual fragments, one of which is the area of the so–called Tuzla estuaries. In January 2010 was created Tuzlovsky Limany National Nature Park. Its territory includes: the water area of the lakes Burnas, Alibey, Hadjider, Shahany Lagoon, Karachaus, Malyi Sasyk and Dzhantshey, the Black Sea sandspit, the mouths of the wetlands of the Alkaliy rivers, the Hadjider and the small rivers flowing to the lakes Shahany and Karachaus, as well as the forest tract «Lebedivka»– artificially planted forest area.

As one of the most interesting and informative routes of the Odessa region, which includes elements of ecological, rural, ethnic and extreme tourism, are offered a pedestrian ecotourist route «Reserve coastline of Odessa region», which runs from the resort of Serhijivka to the village Primorsk (Kiliysky district), which is located 18 km from the city of Vilkovo. The total length of the route is 85–90 km, part of the trail passes through the territory of the national nature park «Tuzlovsky limany».

The area is a plain–wavy steppe (South Bessarabsky steppe), dissected by ravines and beams, and is also characterized by diverse flood landscapes, specific flora and fauna. The heights of the surface are reduced here from north to south, to the sea. The flat surface is disturbed by valleys of rivers, gullies, ravines. Hydrography is represented mainly by the river Danube and the Black Sea coast. In the marine part of the Danube plain there are lake–estuaries between the rivers of the Danube–Dniester, according to the accepted typing, to periodically closed estuaries. These reservoirs have a number of shallow branches, which are highly saline and swampy floodplains of small steppe streams. With the exception of the lake Sasyk (Kunduk), the axis of other reservoirs is parallel to the seaside, sandspit. From the sea, periodically closed estuaries are separated by a sand dune (bar). The total length of the bar from the estuary of Sasyk to the Dniester estuary is 55 km, and the width varies from 50 to 400 m. Among the estuaries of the Danube–Dniester rivers, the estates of the Tuzlov group – Shagans, Alibey, Burnas – occupy a special place. They have an international sta-tus (included in the so–called Ramsar List of wet-lands), as they play an important role in the natural functioning and interaction of coastal ecosystems around the Black Sea. Tuzla estuaries are important for maintaining the biodiversity of the region; provide wintering of many species of birds. Here about 1 thousand pairs of waterbird nest and up to 120 thousand individuals form seasonal clusters, which are especially appreciated by bird watchers. Generally, 243 species of birds are found in the park, of which 28 are included in the Red Data Book of Ukraine.

Since the park has been functioning quite recently so recreational activity is almost not developed. Its borders are not yet identified on the ground, there are no barriers, no sign indicating the value of this territory, the park remains unprotected on weekends when there is a mass arrival of hunters and fishermen. There are no good tracks connecting large settlements or Ukraine with neighboring countries, which is why it significantly influences the number of tourists who could visit the park. There are, of course, roads that connect district centers, but it is worth turning aside and the roads disappearing altogether. Therefore, despite the unique places suitable for recreation, the number of tourists by an order of magnitude less than it could be, because of the unsuitability of roads, only fans of fishing, despite the impassability come here to fish. And if the leadership of the national park is actively starting to introduce various measures – to create tourist routes, excursion and walking ecological and educational paths, to equip places for overnight stays for recreation and to work full time, the park area will attract more tourists, which in turn will attract funds to the local budget.

Conclusions. The development of natural tourism in protected areas can carry a whole range of different consequences – both positive and negative. On the one hand, the development of tourism in many parts of the world was a powerful incentive for the protection of rare species and unique ecosystems, since natural tour-ism is one of the few forms of economic activity that is «inexhaustible», which does not involve the removal of wildlife objects (with the exception of hunting and fishing tourism). But without proper control and management successes in the development of natural tourism can quickly turn into a «reverse side». An unprecedented increase in the number of supporters of natural tourism has created a complex of problems that fifty years ago nobody could imagine. Excessive and uncontrolled flow of tourists is often the cause of degradation of the natural environment, reducing biological and cultural diversity. Negative effects from tourism can extend beyond the boundaries of protected areas, affecting the interests of local settlements. It is noted: those places where the inflow of visitors has increased significantly, may subsequently suffer a rapid decline in tourism business – because the participants of natural tours attracts the very opportunity to feel «far from all». Strong flows of tourists, causing the destruction of natural areas and reducing their attractiveness for future visitors, «switch» to other regions, leaving behind polluted beaches, frustrated local residents and ruined local economies. In this case, we can say that along with the destruction of the environment on which it depends, tourism kills itself. Therefore, when planning regional development, including tourism, priority should be given to preserving its natural «base», including the identification of recreational opportunities of nature resources and the determination of the value of recreational loads on the landscape complexes of nature reserves.

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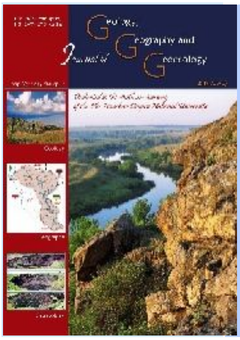

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Dynamics of ecological stability of small towns in Kyiv region

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Abstract. The purpose of this study is to provide a comprehensive assessment and comparative analysis of the ecological balance of territories of the three key small towns in Kyiv region: Boyarka, Vyshneve and Irpin, as well as tracking the dynamics of ecological stability of the towns‘ territories in the system of general planning. The following indicators of anthropogenic transformation and natural protection of urban areas were calculatedaccording to known methodsbased on data available from the towns‘ new Master Plans: coefficients of anthropogenic impact, anthropogenic transformation, nature protection, and ecological stability, absolute and relative tension of the ecological and economic state. The rationality of general planning in terms of ecological balance of urban areas is estimated. The study established that the territory of the town Irpin is characterized by moderate anthropogenic impact, while Boyarka and Vyshneve demonstrated a high level of anthropogenic impact. The total area of the environmental fund on the territory of cities ranges from 13.9% (Vyshneve) to 47.5% (Irpin) of the total area of their territories, which is insufficient in all cases. Currently, the territory of Irpin is the most balanced in comparison with other towns. Implementation of the new Master Plans of the cities will improve the ecological balance of the Boyarka and Irpin areas; improvement in Boyarka will be notably extensive due to the expansion of the city boundaries by a threefold increase in the town‘s area. The projected general development of Vyshneve will worsen the ecological balance of its territory, despite the foreseen expansion of its boundaries. The pressure from the ecological and economic status of the territories is not balanced by the degree of anthropogenic impact and the potential of the sustainability of nature. For the territory of towns, the potential for sustainability of nature is significantly exceeded and requires the expansion of the environment of a stabilizing group of lands. The areas of towns within the existing boundaries are environmentally unstable, the tensions in the ecological and economic conditions of the territories are not balanced, which testify to their ineffective organization. A significant correlation has been found between the calculated coefficients and the area percentage of the environmental fund of urban areas. The obtained data testifies to the expediency of using the indicated eco-geographical indicators within the system of general planning in order to optimize prospective solutions.

Keywords:*urban landscape, anthropogenic impact, anthropogenic transformation of landscape, eco-geographical indices*

Динаміка екологічної стабільності малих міст Київщини

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Анотація. Метою дослідженняєкомплексна оцінка і порівняльний аналіз екологічної збалансованості територій трьох малих міст Київської області – Боярки, Вишневого та Ірпеня з аналізом динаміки екологічної стабільності їх територій у системі генерального планування. За даними Генеральних планів міст розраховано показники антропогенного перетворення і природної захищеності міських територій. Встановлено, що територія м. Ірпінь характеризується помірним, а міст Боярка та Вишневе – високим антропогенним навантаженням. Загальна площа екологічного фонду на території міст коливається від 13,9 (Вишневе) до 47,5% (Ірпінь), що в усіх випадках є недостатнім. Території міст в чинних межах екологічно нестабільні, напруженість еколого-господарського стану територій не збалансована. Реалізація Генеральних планів міст покращить екологічну збалансованість територій Боярки та Ірпеня, причому Боярки – кардинально за рахунок трикратного розширення межі міста. Прогнозований генеральним плануванням розвиток м. Вишневе погіршить екозбалансованість його території не зважаючи на передбачене її розширення. Виявлено високий кореляційний зв’язок між розрахованими коефіцієнтами та відсотковою площею екологічного фонду міських територій. Отримані дані свідчать про доцільність використання зазначених екогеографічних показників у системі генерального планування з метою оптимізації перспективних рішень.

Ключові слова: *урболандшафт, антропогенне навантаження, антропогенна трансформація ландшафту, екогеографічні показники*

Introduction. One of the objectives of sustainable development strategy is to ensure ecologically safe land use, while in general the state of land resources of Ukraine is assessed as being close to critical (Khryshchuk and Bezpalko, 2013; Prykhodko, 2010). At present, the anthropogenic and technogenic impact on the natural environment in Ukraine is several times higher than the corresponding indicators of developed countries of the world (Khryshchuk and Bezpalko, 2013). A significant number of problems in the field of rational land use remain unresolved, the laws of ecologically safe nature management are violated, and anthropogenic impact is adversely affecting the sustainable development of land use.

In general, there are no virgin ecosystems left in the world. Our planet is a mosaic of ecosystems, from relatively intact, to completely rebuilt (Adler and Tanner, 2013). In the era of rapid urbanization, urban ecology has become the main environmental area, and the most important direction of its research is the sustainability of towns (Wu, 2014; Wilson, 2014). The tendency to create sustainable and stable towns is increasing; there is a unique opportunity to apply the results of scientific research in practice, to create environmentally clean towns of the future (McDonnell and Hahs, 2013). The stability of the towns depends to a large extent on the stability of the Earth, although the concept of sustainability remains neglected in modern urban planning (Ahern, 2011). It was precisely because of the concern for the sustainability of the towns that a new paradigm emerged – the ecology for the town, which increased the scale of research of urban ecosystems, and its important direction is the use of the theory of spatial urban heterogeneity as a key element of the town's functional activity (Pickett et al., 2016; Pickett et al. 2016a). In urban systems, the concept of environmental degradation has not yet been applied, except for the false but generally accepted assumption that urbanization itself is an obstacle, and therefore towns are permanently disturbed systems (Grimm et al., 2017).

Urbanization continues to be a global transformational process that affects the integrity of ecosystems, health and well-being of people. Despite the fact that towns as centers of production and consumption of goods and services worsen the natural environment, there is also evidence that urban ecosystems can play a positive role in ensuring sustainable development (McHale et al., 2015). Towns all over the world face an increasing diversity of problems , the solution of which should make them more sustainable (Childers et al., 2015).

The current land use system should include its study in certain areas, in particular environmental, which involves the creation of efficient land use in the following sequence: environmentally safe land use - economically feasible - socially significant (Khryshchuk and Bezpalko, 2013). No matter how the approaches to the implementation of the idea of sustainable development on a global scale are developed, the main node of problems and contradictions, the search for solutions to them lies in specific territories.

According to V. Kalmanova (2016), an ecological approach can only be used on the basis of strict environmental restrictions, which will allow the requirements for the preservation of the natural environment to be taken into account. At the same time, the system element can degrade or completely destroyed in order to take into account the interests of the global optimum. Currently, in the territorial planning system, predominantly, the urban development, rather than the environmental protection dominant, is preserved.

The environment changes under the influence of anthropogenic impact, which is characterized by changes in land use. The area of suburban zones is growing; urban infrastructure is expanding in rural areas. Modifications to land use lead to significant changes within the natural environment (Noszczyk et al., 2017). Regional differences in land use are the result of changes in anthropogenic impact on nature, as well as the impact of natural and social conditions of regions or settlements (Prus et al., 2017). Changes in socioeconomic, environmental, cultural and other conditions lead to global changes in the environment (Louca et al., 2015, Baśski and Mazur, 2016). Agglomeration is characterized by an unprecedented rate of residential development and the transformation of transport communications, which makes research into green plantations in the context of a rapidly changing urban environment relevant (Pogorelov and Lipilin, 2017).

Conceptual approaches to landscape-ecological optimization of the territory, based on statements by I. Pozniak and N. Tsaryk (2013), include the implementation of a number of step-by-step measures, in particular the definition of landscape-ecological criteria and priorities for the development of regional economic systems, the achievement of optimal relationships between economic and natural lands, optimization of a biocentric-network structure of landscape systems – the natural channel of prospective ecological networks.

An urbanized area is a dynamic complex that is constantly expanding and needs to be ecologically balanced. The solution to this problem is impossible without the use of environmental assessment methods, analysis and forecasting of changes in the envi-ronmental situation (Kichata, 2013). Quantitative determination of spatial heterogeneity of land cover in urban systems plays a crucial role in the development of the ecological component of towns (Zhou et al., 2014). The method of quantitative estimation of integrated heterogeneity of urban areas has been proposed, involving rethinking approaches to the classification of urban land use and quantitative assessment of the urban landscape structure, which contains both built-up and unbuilt components (Cadenasso et al., 2007). The interrelation between the system of intensive land use and ecological safety of landscapes from the standpoint of urban sustainable development has been explored (Zhou et al., 2014). It has been noted that built-up areas are a major factor in the impact on environmental safety (Cen et al., 2015). By assessing landscape dynamic processes and analyzing long-term land-use trends, it is possible to obtain important spatial information for landscape planning and ecosystem management (Frelichova and Fanta, 2015).

A promising direction of geo-environmental research is the comparative analysis of the structure of land plots of administrative territorial units (Voronovich, 2016; Kochurov, 2003). Comparative studies of urban areas allow us to verify the suitability of conclusions and generalizations for towns with different social, historical and environmental conditions (Hahs et al., 2009). A model of urban sustainability is developed, based on long-distance comparisons, whose key goal is to take into account the processes by which towns become more sustainable (Childers et al., 2014). The conceptual framework for comparative research in different towns must also be developed (McPhearson et al., 2016). An assessment of the environmental sustainability of any territory is needed as a basis for developing proposals for its systemic economic and environmentally sustainable harmonious development (Glukhovskaia and Evstifeeva, 2016), sustainable land use planning (Getmanskii, 2013). The degree of environmental equilibrium depends not only on the area of green spaces, but also on the natural and economic characteristics of a particular town and its suburban zone, and the results of research on one town cannot be interpreted to characterize another (Narbut and Mirzekhanova, 2016). The statistical information can serve as the information base for research of the town structure (Nychaia and Tarasiuk, 2016). The predominance of anthropogenic-man-made, irreversibly altered landscapes in the town's structure indicates their unstable state (Barmin and Nikulina, 2011). Instead, the underdeveloped spaces are a treasure and determine the overall ecological well-being of the territory not only of the town, but of the region and the country as a whole. Ecological lands should form the main link in the system of optimal organization of the territory (Narbut and Mirzekhanova, 2016).

In the conditions of intensification of nature use geosystems undergo increased anthropogenic impacts, which leads to destabilization of the ecological state of the territories and worsens the quality of life (Orlova et al., 2006). The development of sound methods of regional management of natural resources should be based on knowledge of the current state of the territory (Panchenko and Dyukarev, 2015). Aggravation of the problem of rational land use leads to an assessment of the ecological state of land use and the search for new scientific approaches to improve the criteria for optimizing them (Khryshchuk and Bezpalko, 2013). The intensity of land use can be characterized by such bioindicators as the coefficient of anthropogenic impact on the landscape and the ecological sustainability factor based on the categories of land use (Prus et al., 2017). The limitation is that the statistics are not spatially specific and do not provide qualitative information about the ecosystem (Frelichova and Fanta, 2015).

Ecological assessment of the territory is the basis of the development of environmental policies aimed at creating a sustainable nature management system (Kochurov, 1999). For the first time, the formula for assessing the ecological stability of the landscape was derived by Slovak scholars E. Clementov and V. Heinig (Glukhovskaia and Evstifeeva, 2016), and then actively used and improved by B. Kochurov and others. Currently, there are different approaches to the criteria and methods of environmental assessment of the territory (Khryshchuk and Bezpalko, 2013; Ivan and Chebenova, 2016), which is based on the ranking of land by nature and the level of human impact. More often geoecological estimation of the territory uses the coefficients of anthropogenic impact, ecological stability and natural protection of the territory (Bodrova, 2013), which allow one to determine the degree of balance of the land structure of the administrative-territorial unit and reflect the stability of natural systems. Unlike the index of tree cover and plowing area, the coefficient of natural protection is integral and can be used for a comprehensive assessment of the territory (Kochurov, 2003). The calculation of a complex integral indicator allows one to determine the potential of the environment, that is, the natural resource. The coefficient of ecological stability of urban territory is one of the indicators that enable one to evaluate the effectiveness of the existing system of greening of a town and to create a comfortable environment (Ivleva, 2015).

A common model of resource-preserving use of nature was developed by B. Kochurov's concept of ecological and economic balance of the territory, focused on balanced and environmentally safe territorial development taking into account specific landscape-environmental conditions (Kochurov, 2003; Minnikov and Kurolap, 2013). It is believed that the optimum ecological and economic status of the territory is characterized by the ratio of relative anthropogenic stress (Minnikov and Kurolap, 2013). An important element of the analysis of the current use of land resources in a particular territory is the definition of its anthropogenic transformation based on the correlation of land of different functional use in the general structure of the land fund of the region (Khryshchuk and Bezpalko, 2013), which is one of the most important components in the development of measures for systematic ecological management of the region, environmental policy and optimization of land use.

Comparative studies have different scales. Most geoecological studies are devoted to the assessment of the ecological balance of the regional territories (Getmanskii, 2013; Glukhovskaia and Evstifeeva, 2016, Khryshchuk and Bezpalko, 2013; Orlova, 2006; Prus et al., 2017), the territory of oblasts (Bodrova, 2013; Minnikov and Kurolap, 2013; Glukhovskaya, 2017), separate districts (Voronovich, 2016; Khryshchuk and Bezpalko, 2013), to a lesser extent – the study of urban areas (Ivleva, 2015; Kichata, 2013; Narbut and Mirzekhanova, 2016; Petrishchev and Dubrovskaia, 2013; Zibtseva, 2018).

Thus, there is a wide range of methods for determining the stability of territorial complexes of different rank, although, in our opinion, in essence, they do not have a fundamental difference: all are based on the definition of the quantitative (percentage or absolute) ratio between the different degrees of anthropogenic impacts on territories (ecologically stabilizing and ecologically destabilizing) or on the determination of the share of economically stabilizing territories in the total area of the object. Unlike the post-Soviet space, we have not found such a wide differentiation by the names of coefficients in the works of European researchers, where they usually have the common name "coefficient of ecological stability" (Ivan and Chebenova, 2016). We consider it expedient to try different approaches to the possibility of their use for the assessment of urban areas, which taken as a complex should improve the quality of the analysis of the results.

The research is carried out within the framework of development of conceptual foundations of the system of green plantations in small towns of Kyiv region in the context of ecologically balanced development. The problems of sustainable development of small towns are among the most important issues discussed in the last decades by the world and European community (Bilokon, 2008). The majority of the population of the Kyiv region (68.1%) lives in towns, twenty of them are small towns (77%). This category is the most widespread and least studied. Intensive urbanization (especially in the metropolitan region) and the strategic course on sustainable eco-balanced development make research on the current state of small towns extremely relevant.

The purpose of the study is a comprehensive assessment of the ecobalance of the territories of three small towns of Kyiv region - Boyarka, Vyshneve and Irpin, with an analysis of the dynamics of ecological stability of the territories in the system of general planning.

Material and methods of research. For the analysis of the ecological balance of the territories of small towns, indicators of anthropogenic transformation and natural protection of the territory were determined, namely: coefficients of anthropogenic impact, anthropogenic transformation, nature conservation, environmental sustainability, ecological stability, absolute and relative tension of the ecological and economic condition of the territory of towns. To calculate the indicators, statistical data on the territory of towns (Form 6-Land) and publicly available data of the explanatory notes of the recently developed Master Plans of towns were used (Retrieved from http://boyarka-inform.com/r_29_05_2014_plan.html; http://vyshneve-rada.gov.ua/files/rada/18/pz-gp-vyshneve.pdf; https://imr.gov.ua/for-citizens/generalnij-plan).

The towns investigated – Boyarka, Vyshneve and Irpin belong to the category of small towns, as their population is 34.6; 38.5 and 41.5 thousand people, respectively, i.e. not more than 50 thousand people. The towns are located in the central part of the region, in the southwest direction from Kyiv: Vyshneve – 1.5-2 km from the ring road, Irpin – 15 km, Boyarka – 23 km (Fig. 1) and are part of suburban metropolitan area. The towns are characterized by the same geological conditions (deluvial-eolian and eluvial deposits), in terms of tectonic zoning they are located on the Ukrainian shield, on the Kiev Plateau. According to agroclimatic zoning, the towns of Boyarka and Vyshneve belong to the Kiev highland region (the Forest-Steppe zone), and the town of Irpin – to the area of Kyiv Polissya – territories of sufficient heat supply and moderate humidification. Living conditions for the towns of Vyshneve and Boyarka are estimated as satisfactory, and for the town of Irpin – as moderately favourable. Vyshneve can be described as an industrial town, and Boyarka and

Irpin – as multifunctional resort towns. According to the General Plans, the territorial resources of the towns within the existing limits are very limited: vacant ter-ritories for construction are almost absent; the existing construction is very dense. The proposals on prospective boundaries of towns fixed in the Master plans provide for the inclusion of additional territories at the expense of territories administered by councils of the neighboring villages. At the same time, the general plans declare the creation of a clearer zoning of the territories of towns and the rational use of land.

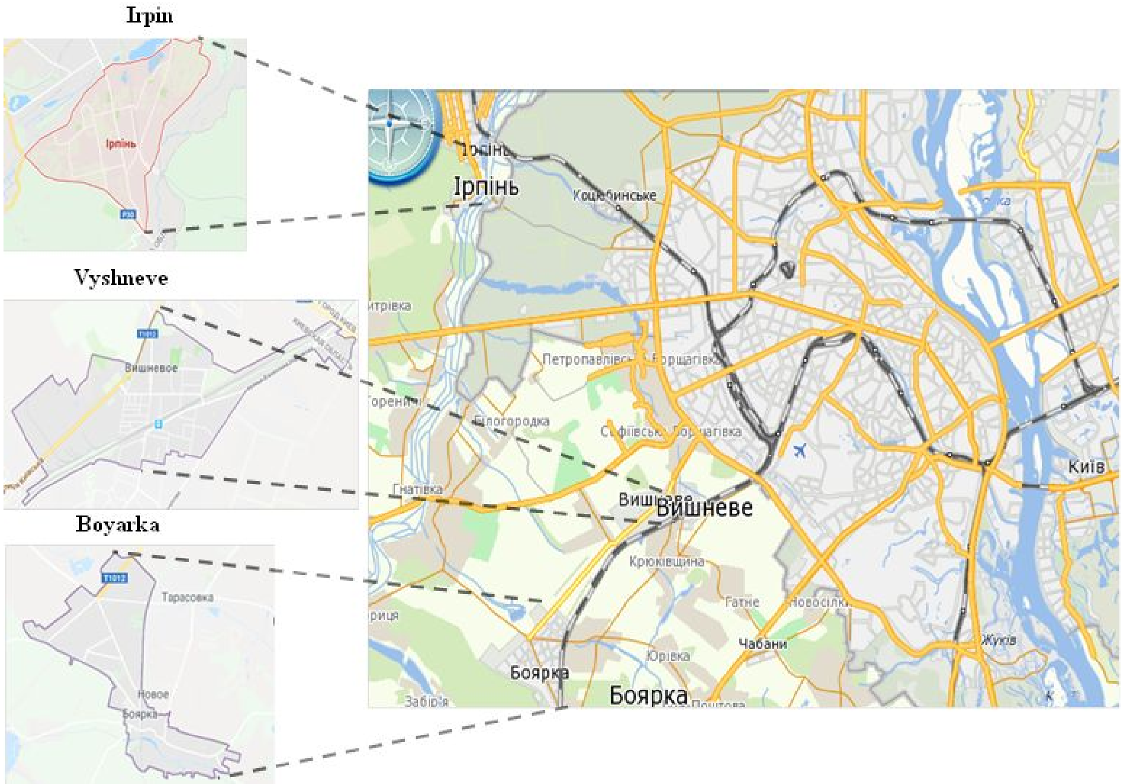

Fig. 1. Scheme of the location of the researchedtowns in relation to Kiev and the configuration of their territories

In order to assess the degree of balance of the territorial structure of towns, the integral indicators described by S. Volkov (2001) are used: the coefficients of ecological stability of the territory, the coefficient of anthropogenic impact. The assessment of the environmental fund and the coefficient of nature protection of the territory were carried out according to the method of B. Kochurov (2003). Types and categories of land in the general plans of the towns did not always coincide with the methods described, so the method of expert assessments of land use received points in accordance with the degree of anthropogenic transformation from low (1 - water surface and the territory of the nature reserve fund) to the highest (5, 6 or 10 points - industrial land). The coefficient of anthropogenic impact was defined as the weighted average score on the existing areas of land of a certain type of land use and their relative scores; the coefficient of anthropogenic transformation of the territory - as the ratio of the area of land to agricultural lands, buildings and roads to the total area of the territory (Kurhanevych & Shipka, 2012); the coefficient of environmental sustainability of landscapes - as the ratio of the area of stable elements of the landscape to the unstable.

The ecological stability coefficient was calculated as the ratio of areas under different types of land use, taking into account the relevant indices (ecological significance of the categories of land characterizing the impact of biotechnical elements on the environment) for (Butrym, 2013; Glukhovskaia and Evstifeeva, 2016) to the total area of the land with an amendment for coefficient of morphological stability of the relief (0.7). The obtained results were evaluated using the appropriate scale (Table 1).

Table 1. Scale of assessment of ecological stability of the territory

Coefficient of environmental sustainability	Ecological state	Coefficient of anthropogenic impact	Level of anthropogenic impact
≤0.33	Environmentally unstable	4.1-5.0	High
0.34-0.50	Weakly stable	3.1-4.0	Increased
0.51-0.66	Medium stable	2.1-3.0	Average
≥0.67	Environmentally stable	1.0-2.0	Low

In order to assess the ecological and economic balance, the level of anthropogenic impact (*AI*) was initially determined, for which, based on expert assessments, each type of land use, taking into account its ecological status, provided an appropriate point. Then, based on the calculation of the anthropogenic impact (AI_n), the level of *AI* for each territory was determined (Kochurov, 2003; Panchenko and Dyukarev, 2015) by the formula 1:

$$AI_n = r \cdot S_r, \quad (1)$$

where *r*– the point of anthropogenic impact; S_r– share of this category of land in the total urban area,%.

The coefficients of absolute (K_a) and relative (K_r) stresses of the territory were calculated as the ratio of the area of land with high anthropogenic impact to the area with lower impact by the formula 2:

$$K_a = \frac{AI_6}{AI_1}, \quad (2)$$

The value of the coefficient of absolute stress on the territory $K_a$allows us to assess the situation by "marginal" criteria. For a more detailed analysis of the territorial balance according to the structure of land use and the natural-ecological potential, the ratio of the relative stresses of the territory $K_r$was calculated on the ratio of 3:

$$K_r = \frac{AI_4 + AI_5 + AI_6}{AI_1 + AI_2 + AI_3}, \quad (3)$$

If $K_r$is equal or closer to 1, then the ecological and economic situation is estimated as balanced by the degree of anthropogenic impact and the potential of sustainability of nature. Territories which experience a high degree of anthropogenic impact have the lowest natural protection. If the area of the lands included in the ecological fund with a minimum *AI* are taken as P_1, then the area of land with a conditional assessment of the degree of *AI* in 2, 3 and 4 points will be respectively 0,8R_2, 0,6R_3, 0,4R_4 (areas of high point of *AI* are not included in the calculation) (Kochurov, 2003). Thus, the total area of land with environment and resource-stabilizing functions (R_{ef}) was estimated by the formula 4:

$$P_{ef} = P_1 + 0{,}8\,P_2 + 0{,}6\,P_3 + 0{,}4\,P_4, \quad (4)$$

where 0,8; 0.6 and 0.4 – corrective factors; P_1, P_2, P_3 and P_4 – lands included into the ecological fund with a conditional assessment of the degree of *AI* in 1, 2, 3 and 4 points.

For the integrated assessment of the territory, the integral coefficient of natural protection (K_{np}) was used, which was determined by the formula 5 (Kochurov, 2003):

$$K_{np} = \frac{P_{ef}}{P}, \quad (5)$$

where *P* – total area of the researched territory (town).

The value of the coefficient of natural protection of less than 0.5 indicates a critical level of protection of the territory.For estimation of the antrhropogenic transformation, the integral index (the index of regional human transformation of natural systems) of K. Hoffmann, specified in by P. Shishchenko (1999) and Khryshchuk and Bezpalko (2013) was calculated by formula 6. The peculiarity of the calculation is to rank the land by 10 categories. In our studies in the towns there were 8 because no areas that belong according to the method to rank 3 (swamps and wetlands) and rank 9 (reservoirs, canals). The areas of the ranks were used in percentage indices and we calculated the depth of landscape transformation.

$$K_{at} = \frac{\sum_{i=1}^{n} (r_i \cdot p_i \cdot a_i)}{100}. \quad (6)$$

In the formula: K_{at}– coefficient of anthropogenic transformation; *r*– rank of anthropogenic transformation of the territory by a certain type of nature use; *p* - area of rank, %; *a*– index of depth of transformation of landscapes; *n*– number of types within the boundary of the region. In this technique, dividing by 100 is used for ease of use of the values of the coefficients. Each type of land use is assigned the rank of anthropogenic transformation and the index of the depth of transformation (Table 2), where the residential housing development was interpreted as rural, and multi-apartments – as a town.

Table 2. Ranks and indices of the depth of transformation of natural systems by different types of land use

Types of land use	Rank of anthropogenic transformation	Index of depth of transformation
Nature Reserve Territories	1	1.00
Woods	2	1.05
Swamps and wetlands	3	1.10
Hay fields	4	1.15
Gardens, vineyards	5	1.20
Arable land	6	1.25
Rural building	7	1.30
Urban development	8	1.35
Water reservoirs, canals	9	1.40
Industrial use land	10	1.50

Taking into account the considerable range of oscillations of the K_{at}, a five-tier scale of its interpretation is used (Table 3), the content of which was the assessment of the ecological state of the landscape, as well as the classification of the ecological and economic status of the territory.

Table 3. Scale of anthropogenic transformation of a landscape

The value of the coefficient of anthropogenic-technogenic transformation K_{at}	Category of anthropogenic-technogenic transformation of the landscape
2.00-3.80	Low transformed territory
3.81-5.30	Transformed
5.31-6.50	Moderately transformed
6.51-7.40	Highly transformed
7.41-8.00	Excessively transformed

Correlation relations between the calculated coefficients, as well as coefficients and share of the environmental fund in the total area of urban areas are established.

Results and their analysis. According to (Butrym, 2013), the built-up lands occupy 5.6% of the territory of the region (in 2010, together with the town of Kyiv) in the structure of the modern land use of the Kyiv region, and they are one of the most complex and most intensively growing types of anthropogenic landscapes.

Ranking of land use of the territory of the researched towns by the degree of anthropogenic impact is given in Table. 4, and the percentage of the modern and planned structure of urban lands by the degree of anthropogenic impact is illustrated by Fig.2.

Fig. 2 indicates that the territory of the town of Irpin is the most balanced: in addition to the lands ranked at 1 point, which make up 3.3% of the total territory of the town, the remaining ranks make up almost equal proportions- from 22.7 to 26.2% of the urban territory. According to the planning, the area of land of grade 3 (due to towns and other lands) will be significantly reduced (down to 0.8%), the area of land of rank 4 will increase (from 24.5 to 32.3%) and the percentage of land of rank 1 will increase to 12.6 % due to the expansion of the lands of the nature reserve fund. As a negative phenomenon from the point of view of the ecological balance of the territory, one can consider the prospective growth of the area of territory under heavy anthropogenic pressure (ranks 4 and 5) from 50.7 to 57.0%.

Table 4. Classification of land by the degree of anthropogenic impact

Types and categories of land	Point	Boyarka		Irpin		Vyshneve		K*
		now	plan	now	plan	now	plan	
Residential apartment buildings	5	43.7	125.5	51.2	148.2	96.8	213	0.05
Houses with gardens	4	426.0	567.5	724.3	909.8	67	97	0.5
Enterprises, institutions, establishments	5	111.1	170.0	260.4	372.4	43.8	124	0.05
Landscaped territories of general areas of use GU**	4	18.6	84.6	30.0	106.6	4.8	62	0.43
Streets, roads, squares	5	186.0	221.0	145.7	246.0	102.1	237	0.03
Industrial area	6	64.7	167.5	101.3	109.0	105	125	0.03
Municipal and warehouse	5					190	200	0.03
Recreation bases	4			106.2	146.0			0.05
Garden societies	4	161.0	44.6	46.6	35.6			0.43
Cemeteries	3	4.8	4.8	19.8	30.0			0.7
Waters, nature reserve fund	1	10.9	10.9	122.4	466.0	0.5	2	0.79
Beaches, gardens, swamps, other	3	12.3	12.3	820.7		34.1		0.1
Other green plantations	2	61.7	262.1		1098.5	60	91	1
Woods	2	21.2	1718.2	962.0				0.38
Plots with start of construction	5			314.5	37.0			0.03
Total		1122	3389	3705.1	3705.1	704.1	1151	

Note: K * is the coefficient of ecological significance of the territory (Volkov, 2001; Glukhovskaia & Evstifeeva, 2016); GU ** - landscaped territories of general use. In the town of Boyarka, in the category of "garden societies", taking into account the real specifics of the territories, the territory of the forest research station, the state institution "Ukrcentrcadrilliss", and the college garden are also classified. In the town of Irpin, the category of "recreation centers" includes the resort and recreational areas, and the category of "garden societies" includes agricultural areas.

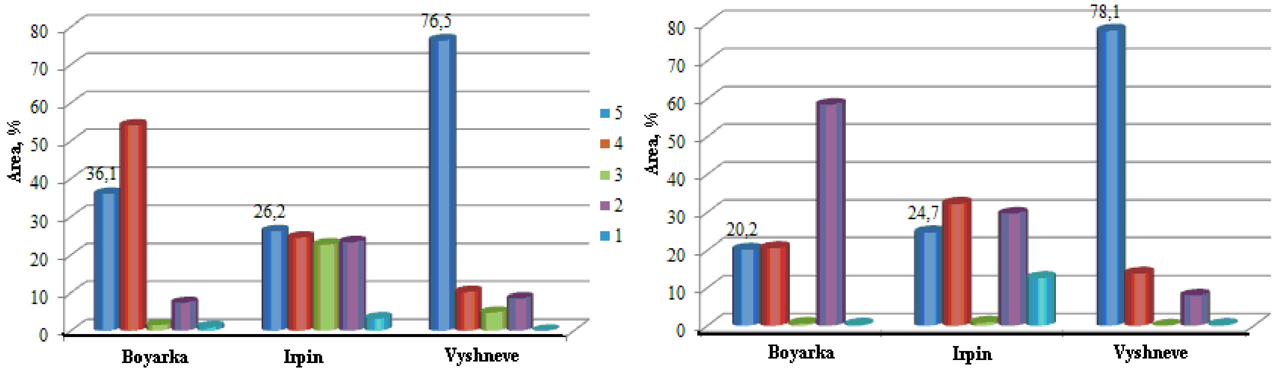

Fig. 2. Contemporary (*a*) and planned (*b*) structure of urban lands by the degree of anthropogenic impact (1 - 5 points), %

On the territory of Boyarka, 90.1% of the lands are currently under heavy anthropogenic impact (ranks of land with 4 or 5 points), with rank 4 being the most widespread category of land (54% of the territory), due primarily to the significant area of built- up land . The lands of rank 1 occupy only 1% of the town's territory. In the long term, according to the decisions of the general planning (according to which the town's area is three times larger, and the area of the attached forest is 1.5 times greater than the town's area at the time of the last master planning), the territory of the land of rank 2 will increase to 58.4% mainly due to the increase in the area of forests and the category "other green plantations". The percentage of land of rank 4 and rank 5 is redu-ced (to 20.2% and 20.6% respectively), but at the same time the percentage of land ranked at 3 points will decrease (to 0.5) and the percentage of land ranked at 1 point will decrease by almost three times (from 1 to 0.3%) . In general, for the overall urban area, such shifts appear to be positive.

The worst situation with the distribution of land is on the territory of the town Vyshneve . Both now and in the future, the most common category of land is the land rank with 5 points, the area of which is set to increase in the future (from 76.5 to 78.1%), primarily due to the expansion of land for businesses, streets and squares, apartment buildings. The increase in the area of land rank with 4 points (from 10.2 to 13.8%) will occur due to the creation of green spaces for general use. The area of land-ranking 1 point will increase to 0.2% and the area of land rank with 2 points in the structure of urban areas falls from 8.5 to 7.9%, although in absolute terms this category of land area increases. Thus, despite the planned expansion by 1.6 times in the territory of Vyshneve town, according to the general plan this transformation will be accompanied by a further increase in anthropogenically impacted territories with ranks of 4 or 5 points and bringing their area in the structure of urban land from 86.7 to 91.9 %, and the share of land in the rank of 5 points will increase from 76.5 to 78.1%. Thus, the cardinal expansion of the town's territory will be accompanied by a deterioration and lead to an environmentally unbalanced town territory. The calculation of the area of the environmental fund of urban areas is shown in Table 5.

Table 5. Calculation of the total area of the ecological fund for the territories of research small towns

Coefficient	Points	The area of the ecological fund of small towns, ha					
		Boyarka		Irpin		Vyshneve	
		now	plan	now	plan	now	plan
0.4	4	605.6	696.7	907.1	1198	71.8	159.0
0.6	3	17.1	17.1	840.5	30.0	34.1	0
0.8	2	82.9	1980.3	962.0	1098.5	60.0	91.0
1	1	10.9	10.9	122.4	466.0	0.5	2.0
Total area, ha		1122.0	3389.0	3705.1	3705.1	704.1	1151.0

We have calculated the coefficients of natural protection of the territories of towns at the time of development of their master plans and decisions of prospective general planning, which have the following values:

Boyarka: K_{np}= (10.9+66.32+10.26+242.24)/ /1122.0=329.72/1122.0=0.294;

Boyarka (plan): K_{np}= (10.9+1584.24+10.26+ +278.68)/3389.0=1884.08/3389.0=0.556;

Irpin: K_{np}= (122.4+769.6+504.3+362.84)/ /3705.1=1759.14/3705.1=0.475;

Irpin (plan): K_{np}= (466.0+878.8+18+479.2)/ /3705.1=2112.0/3705.1=0.570;

Vyshneve: K_{np} = (0.5+48+20.46+28.72)/ /704.1=97.68/704.1=0.139;

Veshneve (plan): K_{np}= (2.0+72.8+0+63.6)/

/1151.0=138.4/1151.0=0.120.

The course of calculating the coefficients of anthropogenic transformation of urban areas is shown in Table. 6

Table 6. Calculation of the coefficients of anthropogenic transformation for the territory of the researched towns

Index of depth of transformation	Rank	Area, %					
		Boyarka		Irpin		Vyshneve	
		now	plan	now	plan	now	plan
1.50	10	22.34	11.46	6.67	9.58	56.40	48.82
1.35	8	13.80	8.72	19.76	18.99	19.97	29.28
1.30	7	37.96	16.75	19.55	24.55	9.52	8.43
1.25	6	1.10	0.36	22.15	0	4.84	0
1.20	5	16.01	3.81	2.07	3.84	0.68	5.39
1.15	4	0.43	0.14	0.53	0.81	0	0
1.05	2	7.39	58.44	25.97	29.65	8.52	7.91
1.00	1	0.97	0.32	3.30	12.58	0.07	0.17

Table 7 contains the values of the calculated eco-geographical indices for the territories of there-searched small towns and their approximate estimation relative to the norms.

Table 7. Eco-geographical coefficients of territories of the researched small towns

Coefficient	Boyarka		Irpin		Vyshneve		Norm
	now	plan	now	plan	now	plan	
Anthropogenic impact	4.24	3.07	3.46	3.42	4.69	4.73	≤3
Anthropogenic transformation	0.91	0.41	0.71	0.58	0.91	0.92	≤0.65
Environmental sustainability of the landscape	0.09	1.42	0.41	0.73	0.09	0.09	≥1.01
Ecological stability of the landscape	0.24	0.27	0.19	0.39	0.12	0.12	≥0.67
Natural protection of the territory	0.29	0.56	0.47	0.57	0.14	0.12	≥0.5
Absolute tension of the EEST*	5.94	15.37	0.82	0.23	210	62.5	1
Relative tension of the EEST*	18.94	1.58	1.72	2.94	13.80	28.26	1
Anthropogenic transformation	9.52	5.68	7.30	6.74	12.07	11.74	2.00-3.80
Area of the ecological fund,%	29.4	55.6	47. 5	57.0	13.9	12.0	57-70

Note: EEST * - the coefficient of ecological and economic status of the territory.

According to O. Shevchenko (2005), the land-resource potential of the Kiev region is decreasing, which negatively affects the quality and quantity of other natural resources. At the same time, during the period from 2008 to 2014, the area of built-up land increased by 12.6 th.ha , by 0.5% and amounted to 4.8% of the total area of the region. It is noted that the Kyiv region has low indicators on the level of providing land for recreational purposes and natural and recreational resources (the share of land for recreational purposes does not exceed 0.1%) and re-quires the introduction of environmental principles of recreational nature management (Poltavets, 2013).

Among the priority directions of the development of the territory of the suburban zone of Kyiv, which includes the territory of the researched towns, the general planning presupposes the preservation of a common landscape and recreational system of green spaces, at the same time it is planned to relocate a number of industrial enterprises outside Kyiv, in particular resource-intensive and ecologically harmful, to use the territory of the suburban area for the placement of residential low-rise and multi-storey buildings, communal, industrial, transport and warehouse facilities, which can lead to admiral urbanization of territories. In particular further urbanization of Vyshneve and Boyarka , is foreseen as centers of neighboring district settlement and recreation systems (http://kievgenplan.grad.gov.ua/ua/tekstovi -materiali/15-generalny-plan/76.html).

According to Y. Bilokon, the general plans of small towns should be directed, first of all, to search for territorial resources to increase their sustainability and attractiveness for business and tourism, strictly limiting the sources of environmental and technological danger (Bilokon,2008); in this case, small towns in the future can become the basis for harmonization of social life, social stability and cultural revival of our society.

Our calculations have shown that the coefficient of anthropogenic impact of the researched small towns currently corresponds to the mean value in the region of 3.4 only for the territory of Irpin and is moderate, and for the other two towns, especially for Vyshneve, significantly exceeds the mean value in the region and corresponds to a high anthropogenic impact. For comparison, the magnitude of the anthropogenic impact coefficients for other small towns of Kyiv region – Ukrainka and Obukhov - is respectively 2.78 and 3.66, and for the previously investigated historical town of Vyshhorod – 3.71, which corresponds to the elevated level. Realization of the planned measures for the researched towns will allow reduction of the anthropogenic impact on the territory of Boyarka (to a moderate level) and also to some extent in the territory of Irpin, but will to some extent raise the already high anthropogenic impact on the territory of Vyshneve.

High values of the coefficient of anthropogenic transformation and low coefficient of environmental sustainability of the landscape (pronounced instability) are characteristic of the current state of Boyarka and Vyshneve. Improvement of the prospects for Boyarka will take place through the expansion of the town's territory by three times (encompassing mostly adjacent forest lands), resulting in the Boyarka territory being characterized as conditionally stable. The territory of Irpin will remain unstable, but the situation with this indicator will improve almost twice. For Vyshneve, improving the situation in the calculation period (until 2030) is not expected, and anthropogenic transformation will increase.

The ecological stability of the landscape in the existing boundaries of the towns varies from 0.12 (Vyshneve) to 0.24 (Boyarka), that is, the territories of all towns are environmentally unstable. In the long run, only the territory of Irpin will become unstable. For the territory of Vyshneve this indicator will not improve its position.

The total area of the environmental funds of the towns is currently 13.9% of the urban area of Vyshneve, 29.4% of Boyarka and 47.5% of the territory of Irpin, which according to the data (Poltavets, 2013) accounts for 15.39% of the regional land for recreational purposes. According to the general plans of the towns, the area of the environmental fund of Boyarka and Irpin will approach the optimal value and will accordingly be 55.6 and 57.0%. In Boyarka, such an optimization will take place due to the expansion of the urban area (almost 1.7 th.ha of forests will be added), and in Irpin - due to an increase of more than 0.3 th.ha of the nature reserve fund area and the appearance of 1.1 th.ha other green plantations, which, however, will be accompanied by the disappearance of 962 hectares of forest lands. The area of the ecological fund of Vyshneve, in spite of the 1.6 times expansion of the town's territory, and contrary to the declared objective of ecologically balanced land use, will decrease by 1.9% to 12.0%. The coefficient of natural protection of the territory is currently the most critical for the territory of Vyshneve, although for all three towns this is less than 0.5, which indicates the critical level of protection of the territories of the researched small towns within their existing urban boundaries. In the case of general planning, the coefficient of natural protection of the Boyarka and Irpin areas will increase to 0.56 and 0.57, which will correspond to high natural-ecological potential and resistance to anthropogenic impacts. Instead, the level of protection of the territory of Vyshneve will remain critical, and the coefficient of natural protection of the territory will deteriorate from 0.14 to 0.12.

Thus, the current territories of the researched small towns have a low degree of favourableness (Voronovich, 2016) of the territory (in all cases , a moderate or high anthropogenic impact is combined with a critical value of the coefficient of natural protection).

Significant changes are observed in the absolute and relative tensions of the ecological and economic status of the territories of the researched towns. At present, according to these indicators, the situation is closer to the optimal one only in Irpin, but in the long run even here it will sometimes deteriorate. The coefficient of absolute tension of the ecological and economic status of the Vyshneve is 210 times the optimal value, but according to the plan it is to be doubled, whereas the relative intensity of the ecological and economic condition of the territory will be halved in terms of the plan. The relative intensity of the ecological and economic condition of the territory is currently the highest for Boyarka, but according to the plan it is most important to approach the optimum value. The coefficients of relative anthropogenic stress indicate an unbalanced ecological and economic condition of the urban areas both at the present stage and in the future. High values of the absolute ecological stress factors indicate an unfavourable geoecological situation in the studied territories and justify the need to create a stabilizing environment in the region under research.

According to general planning, the coefficient of anthropogenic transformation of the territory will change from the excess to the average for Boyarka, will remain high for Irpin and excessive for Vyshneve, but with minor positive shifts in both cases.

Between the area of the ecological fund with calculated geoecological indicators (coefficients) a rather high and mostly reliable correlation relationship was determined: the coefficients of correlation vary from 0.86 ± 0.258; P = 0.95 (coefficient of ecological stability of the landscape) and -0.67 ± 0.370 (absolute tension of the ecological and economic condition of the territory, the relationship is unreliable) to -0.98 ± 0.097; P = 0.99 (coefficient of anthropogenic pressure), -0.99 ± 0.082; P = 0.99 (anthropogenic transformation) and 1.00 (coefficient of natural protection of the territory). The closest negative correlation is observed, naturally, between the coefficient of natural protection of the territory and the coefficients of anthropogenic impact and anthropogenic transformation (r = -0.99 in both cases), and positive - between the coefficient of anthropogenic impact and anthropogenic transformation (r = 0.99).

Conclusions. The analysis of the territorial structure of the three small towns of Kyiv region indicates the diversity of trends in the ecological balance of their territories and the feasibility of using ecogeographic indicators in the system of general planning in order to optimize prospective design decisions. The town Irpin is characterized by an average degree of environmental favourableness and its territory is now ecologically more balanced. The territories of Boyarka and Vyshneve have a low degree of favourableness (high level of anthropogenic impact and critical value of the coefficient of natural protection). The analysis of the master plan has shown that the ecological situation will be dramatically improved in the territory of the town of Boyarka due to the threefold expansion of the town boundaries. Instead, the extension by 1.6 times of the boundaries of Vyshneve does not provide for improvement of the ecological balance of the town. In order to ensure the sustainable development of urban areas in general planning we consider it expedient to take into account not only urban, economic and social, but also environmental factors, to link them to a single principle of environmentalization of territories. Proposed measures in the general plans should ensure the strengthening of the natural basis of towns and increase environmental sustainability, which is justified by calculations of integral indicators: the factors of ecological stability of the territory, anthropogenic impact, natural protection of the territory.

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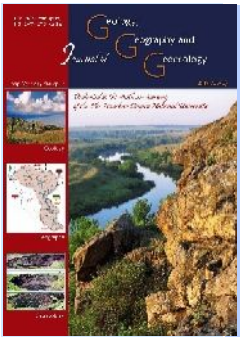

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The dependence of the technosols models functional properties from the primary stratigraphy designs

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Abstract. In the present article the assumption that the design of the soil-like artificial body in zero-moment of existence determines the dynamics and trajectory of soil-forming process was tasted. It was shown that an important aspect of the experiment is the search criteria that you can perform evaluation of the functional properties of the generated structures depending on their organization. The study of the water infiltration dynamics from the soil surface is highly informative non-destructive testing for evaluating the properties of the soil body. Studies showed that technosols as artificial creation have fundamental differences between the natural soils for which the classic Philip equitation was proposed. Technosoils are porous, but heterogeneous formations. The process of filtering in technosols is not laminar, periods of smooth water infiltration is outbreak by disastrous water absorption. To simulate this process it was showed that the better results may be obtained due to originally modified Philip equitation. Specific constant C describes the dynamics of the infiltration process the early stages of the experiment and is a specific indicator for technosols. In natural soils this constant is zero. The sorptivity of the pedozems was reveled to be depended from the underlying layer. Organic components contribute to the formation of aggregate most of which is water resistant. Such formations smooth density variation of clay soil resulting from swelling and shrinkage processes that can maintain stable structure of the pore space. As a result, the soil after phytomeliorative rotation gets such features as reduced infiltration rate, but increased level of filtration. The artificial mixture of clay has significant waterproof properties, which ultimately can lead to complete discontinuance of water absorption by technosols. Waterproof properties of soil may increase the risk of water erosion of technosols. For technosoils structural change of the pore space state are inherent in contact with water because hydrolabile units of their structure. Accordingly, during the infiltration process there are significant changes in the course of the rate of filtration of water.

Ключові слова: конфлікт, екологічний стан, ризик, постконфліктний період, туризм.

Залежність функціональних властивостей моделей техноземів від первинної стратиграфії насипок

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Анотація. У даній статті було перевірене припущення про те, що конструкція ґрунтоподібного штучного тіла у нульовий момент існування визначає динаміку і траєкторію ґрунтотвірного процесу в процесі рекультивації. Було показано, що одним з найважливіших аспектів експерименту є пошук критеріїв, які дають змогу виконати оцінку функціональних властивостей створених структур у залежності від їх організації. Вивчення динаміки вбирання води з поверхні ґрунту є досить інформативним інструментом для оцінки властивостей тіла ґрунту без порушення його структури. Дослідження показали, що техноземи як штучні утворення мають принципові відмінності від природних ґрунтів, для описання інфільтрації яких було запропоноване класичне рівняння Філіпа. Техноземи є пористими, але гетерогенними утвореннями. Процес інфільтрації техноземів не є ламінарним, а періоди гладкої інфільтрації води перериваються спалахами з катастрофічним поглинанням води. Для імітації цього процесу було показано, що найкращі результати можуть бути отримані у результаті оригінально модифікованого рівняння Філіпа. Специфічна для модифікації константа *C* описує динаміку процесу інфільтрації на ранніх стадіях експерименту і є особливою характеристикою техноземів. У природних ґрунтах ця константа дорівнює нулю. Було показане, що сорптивність педоземів залежить від характеру підстилаючого шару. Органічні компоненти сприяють утворенню агрегатів більшість з яких є водотривкими. Такі утворення згладжують зміни щільності глинистих ґрунтів, які виникають у результаті набухання та усадки. Ці процес можуть підтримувати стабільну структуру порового простору. В результаті, після того, як ґрунт зазнав впливу фітомеліосівозміни він набуває таких характеристик, як зниження швидкості інфільтрації, але підвищений рівень фільтрації. Штучні суміші з глини мають значні водотривкі властивості, які у кінцевому рахунку можуть призвести до повного припинення поглинання води техноземами. Водонепроникні властивості ґрунту можуть збільшити ризик водної ерозії техноземами. Для техноземів притаманні структурні зміни порового простору при контакті з водою, тому що їх структура представлена переважно неводотривкими агрегатами. Відповідно, в процесі інфільтрації відбуваються значні зміни в процесі швидкості фільтрації води.

Ключовіслова: техноземи, інфільтрація, рекультивація, стратиграфія конструкцій, рівняння Філіпа

Introduction. Soil is a transitional link from the world of living nature in the world of the inanimate nature, from the biosphere to the geosphere (Karpachevsky, 1983). Soil linkages mechanisms with other biogeoceonosis components and its main feature – fertility are determined by the migration and transformation of matter and energy that occur in the soil depth under the influence of the introduction and removal of biogenic and abiogenic substances (Kharytonov et al., 2018). Material-energy metabolism of terrestrial biogeoceonosis in no small degree depends on the physical condition of the abiotic part of the soil (Karpachevsky, 2005). The soil is a most conservative component of the biogeoceonosis (Anderson et al., 1998). Its buffer properties contribute to the preservation of specific biogeoceonosis type, regulation of thermal and water regimes in biogeoceonosis, toxic substances neutralizing that are formed in biogeoceonosis during his life (Heuvelink, Webster, 2001; Rode, 1984).

In biogeoceonology soil is considered as a part of the internal environment converted by biota (Kunah, 2016). Study of space-time variability of the soils properties allowed to justify the concept of soil ecomorphes as a part of biogeocenotic cover (Zhukov, Zadorozhnaya, 2016). Soil ecomorphes and other biogeocenotic ecomorphes demonstrate regularly dynamics in the gradient humidity and trophicity of soils (Zhukov, Shatalin, 2016). Heterogeneous soil conditions are formed as a result of small biological cycle and determined by key species, creating the diversity of habitats (Zverkovskyi et al., 2017). Features of soil as habitat create ecological space for soil animals (Zhukov et al., 2016). Soil fertility is closely linked to its morphological characteristics, such as the color of the soil itself, the depth of the humus layer, the density of soil structure (Yakovenko, 2008). The soil is a hierarchical multi-level system, each level of which has its own elemental structure (Fridland, 1972).

The gradual formation of morphological structures is occurred in the technosols following the soil formation process after the beginning of their construction, which in the future will be converted into genetic horizons, which are homologous genetic horizons of natural soils (Zadorozhna et al., 2012). The formation of morphological organization of the soil-like bodies leads to gain them functional properties that approach them to natural soils (Zabaluev, 2010). This trend is particularly important in the context of agriculture reclamation which has the goal of restoring the use of the land in agricultural production (Bekarevich, 1971). You can expect that under the influence of general soil-forming factors over time the artificially created soil-like bodies will obtain properties and structure, similar to natural soils. But there remains an unknown trajectory of this process and its duration in time. Variable properties of technosols in space and time can be estimated by a number of informative and valuable indicators (Zhukov et al., 2016).

As a hypothesis can be considered the assumption that the design of the soil-like artificial body in zero-moment of existence determines the dynamics and trajectory of soil-forming process. An important aspect of the experiment is the search criteria that you can perform evaluation of the functional properties of the generated structures depending on their organization.

Materials and methods. At the research station of the State Agrarian and Economic University a field experiment with lysimeters, each of which contains a special combination of rocks or chernozem-like mass was started to test this hypothesis in the 1990s (Fig. 1) (Zabaluev, 2010).

The design of technosolsmodels allow to explore different options of soils combinations (Figure 2). First of all, these monomodels which are made up of only humus material, loess-like loam, reddish-brown clay and loam. Application of humus material is quite natural, since it is by definition is the most fertile and suitable for agricultural use. To some extent, such an option can be considered as control. But the formation of a powerful layer of humus mass does not solve all the problems of reclamation. During technological actions the humus mass properties change significantly so this mass cannot be considered as identical to genetic horizons of natural soil or agrozems.

Fig. 1. Experimental lysimeters to determine the optimal technosols stratigraphy on bioecological research station of the Dnipro State Agricultural and Economic University (Pokrov city, Dnipropetrovsk region, Ukraine)

The most important trend of such mass transformation due to reclamation technological actions is a dehumification. In addition, artificially created layers do not possess constructive strength. This aspect effects considerably on the progress of physical, chemical and biological processes in the technosol. Hence the dynamics of the monomodels with humus material are needed to be investigated. It should be added that the volume of humus material is limited. In this connection there is a need to construct technosols from rocks that are not phytotoxic and have the property fertility (Bekarevich, 1971). In this regard monomodels from rocks should also be regarded as basic. The technological mix of rock in which there is no a horizontal stratification can be seen as monomodel. Indeed, categories such as "blue-green clay", "loess-like loam" or "red-brown clay" is also a technological mixture with predominance of visual components on which such a mixture is named.

More complex models emphasize the idea that influence on the technosol properties may be down by using a combination of different components. These are pedozem variants (humus material from genetic horizons of the chernozems disturbed by mining development is applied for their formation) based on various rocks such as loess-like loam, clay gray-green, red-brown clay and loam. In such models an important aspect of varying is a thickness of the humus layer. Naturally, humus material is always placed on the technosol surface.

More complex models (three- or more component) attract interest, or with a vertical repetition layers in two-component models and their combination (regular repetition of two-component model, which is located on the third type of rock). Tree-component models are usually such that have the goal to create water-proof or waterborne layer (the so-called water-accumulative models) (Zabaluev, 2010). The origin of the rocks for reclamation may also be variable. Rocks can be taken directly from the of career side or after exposure to phytomeliorative rotation. The study of the water infiltration dynamics from the soil surface is highly informative non-destructive testing for evaluating the properties of the soil body.

Optimal infiltration intensity must be accompanied by favorable performance stability over time, which affects the coefficient of permeability. This coefficient, which exceeds 1.5, does not guarantee against the floating of the soil surface and the subsequent formation of crusts even after a short intense downpour (Medvedev et al., 2011). The resulting dynamic curves along with a high resolution differential ability are ecologically relevant, that reflect the properties of the soil as the habitat of living organisms. Important aspects water infiltration parameters are absolute levels of infiltration and filtration and extinction coefficient of the soil permeability.

Studies shown that technosols as artificial creation have fundamental differences between the natural soils for which the classic Philip equitation was proposed. Technosoils are porous, but heterogeneous formations. The process of filtering in technosols is not laminar, periods of smooth water infiltration is outbreak by disastrous water absorption. To simulate this process it was showed that the better results may be obtained due to the more complicated model:

$$Q = S_p \cdot t^{1/2} + A_p \cdot t + B,$$

where B is additional constant. Modeling done in Statistica 7.0 program in module User-Specified

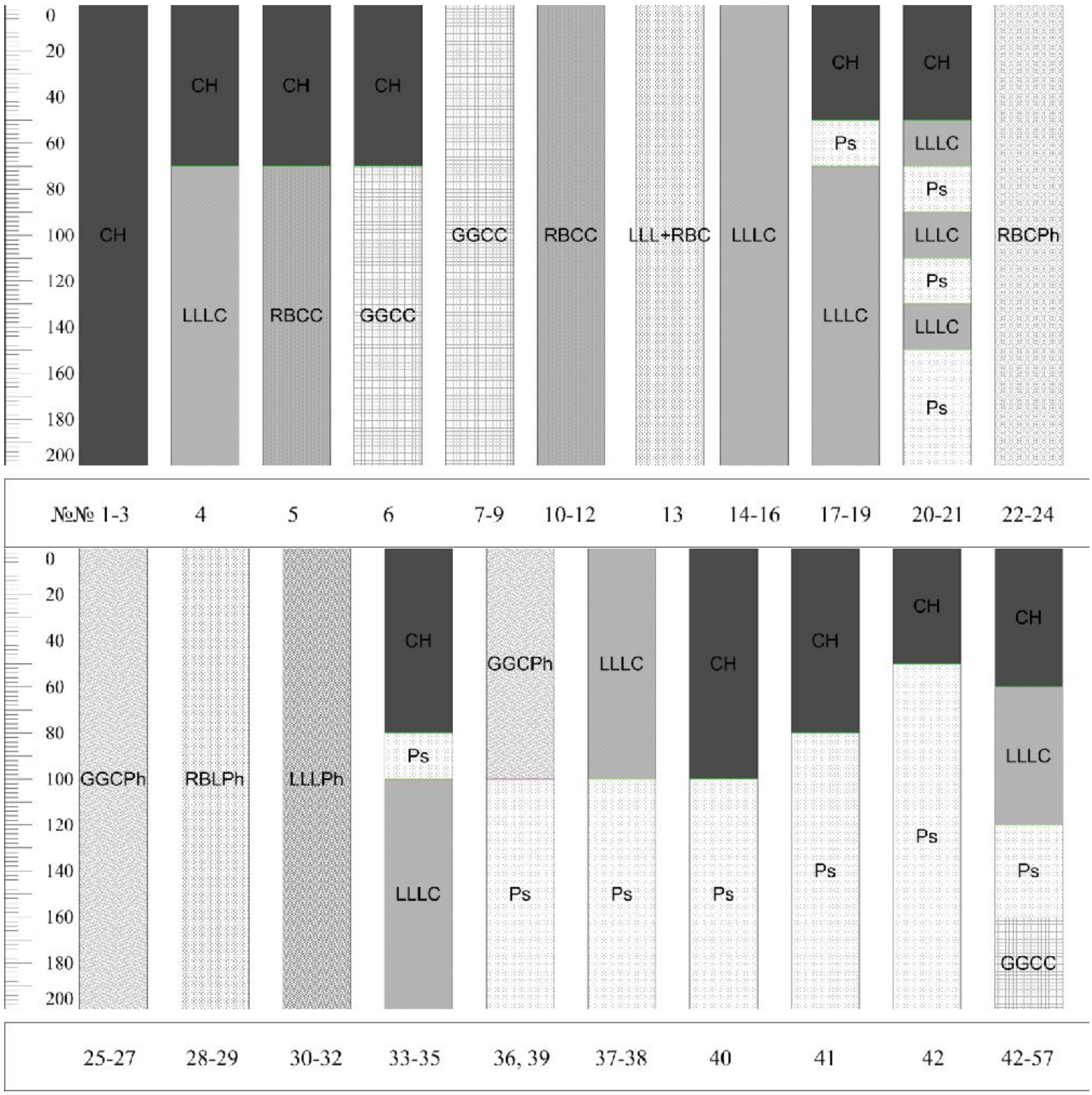

Fig. 2. Stratigraphy of the technosol models (1–57)

Legend: CH – chernozem-like humus mass; GGC_C – gray-green clay from the career side; GGC_{Ph} – gray-green clay after phytomeliorative rotation; LLL+RBC – technical mixture of loess-like loam (50%) and red-brown clay (50%); LLL_C – loess-like sandy loam from the career side; LLL_{Ph} – loess-like sandy loam after phytomeliorative rotation; Ps – sand; RBC_C – red-brown clay from the career side; RBC_{Ph} – red-brown clay after phytomeliorative rotation; RBL_{Ph} – red-brown sandy loam after phytomeliorative rotation.

Regression, method of least squares with Gauss-Newton estimation method.

Results and discussion. The Philip's equation constant is equal to zero. For some technosol models this constant is not statistically significantly different from zero (Table. 1). But constant often takes a negative value. Negative constants indicate the presence of some moisture absorption inhibition in the early stages, or a slower process than is typical for the whole study period. Arguably, air locks can cause slow moisture absorption at the beginning of the infiltration process.

Table 1. Codifying of the technosol models and Philip's equation parameters
(bold showing coefficients significant with $p< 0.05$)

№	Models code			Philip's equation parameters		
	Upper layer	underlying layer	Origin	S	A	B
1	CH	CH	C	**207.44±77.06**	52.86±33.81	43.60±40.28
2	CH	CH	C	**539.61±149.62**	75.66±61.33	–120.20±83.76

№	Models code			Philip's equation parameters		
	Upper layer	underlying layer	Origin	S	A	B
3	CH	CH	C	**465.09±92.87**	**106.32±31.50**	**–147.11±63.71**
4	CH	LLL	C	**746.42±96.46**	6.53±33.41	**–160.95±64.36**
5	CH	RBC	C	**287.05±45.21**	**69.68±15.66**	–60.93±30.18
6	CH	GGC	C	**366.62±133.48**	**233.30±46.13**	–50.76±89.36
7	GGC	GGC	C	**1044.83±54.20**	**–152.89±16.46**	**–164.21±41.61**
8	GGC	GGC	C	**1096.32±38.06**	**–130.29±13.93**	**–191.13±23.95**
9	GGC	GGC	C	**1070.58±46.13**	**–141.59±15.19**	**–177.67±32.78**
10	RBC	RBC	C	**753.81±119.60**	**178.96±43.60**	–139.48±75.55
11	RBC	RBC	C	**30.27±4.66**	**0.66±0.07**	**–364.85±73.31**
12	RBC	RBC	C	**1272.36±98.86**	9.68±35.84	**–327.95±62.94**
13	LLL	RBC	C	**422.04±29.61**	0.78±11.28	**–169.76±17.71**
14	LLL	LLL	C	**487.11±45.14**	**68.82±15.02**	**–102.36±31.09**
15	LLL	LLL	C	**657.95±68.83**	34.81±25.61	**–190.68±42.24**
16	LLL	LLL	C	**939.41±99.74**	–39.03±37.12	**–231.03±61.20**
17	CH	PS	Ph	**198.02±70.08**	**285.36±27.28**	–72.27±41.98
18	CH	PS	Ph	**236.82±78.44**	**258.07±31.44**	–23.13±45.41
19	CH	PS	Ph	105.27±66.89	**265.26±26.50**	–70.72±39.17
20	CH	PS	Ph	52.07±81.90	**373.80±33.71**	42.85±45.96
21	CH	PS	Ph	138.06±96.09	**164.88±39.17**	32.87±53.91
22	RBC	RBC	Ph	**430.40±102.96**	**116.77±46.12**	**–126.72±52.88**
23	RBC	RBC	Ph	**548.57±171.28**	141.63±76.64	–129.87±88.07
24	RBC	RBC	Ph	**564.21±191.12**	62.87±85.54	**–269.93±98.27**
25	GGC	GGC	Ph	**1681.36±151.94**	–20.59±55.55	108.00±93.82
26	GGC	GGC	Ph	**1427.78±70.55**	**–144.43±25.73**	–89.26±43.77
27	GGC	GGC	Ph	**1781.61±56.96**	**–131.14±20.77**	**–129.39±35.34**
28	KBL	KBL	Ph	**1254.28±94.84**	**165.69±35.70**	**455.28±57.54**
29	KBL	KBL	Ph	**184.21±65.54**	**82.82±31.77**	**218.99±31.01**
30	LLL	LLL	Ph	81.69±73.48	**170.01±33.45**	44.18±37.71
31	LLL	LLL	Ph	218.03±107.61	**144.25±48.97**	15.85±55.23
32	LLL	LLL	Ph	144.66±71.86	**113.02±32.91**	56.34±36.64
33	CH	PS	Ph	**351.73±56.92**	13.69±30.15	**743.10±24.40**
34	CH	PS	Ph	**637.60±80.35**	88.46±42.29	**830.13±34.79**
35	CH	PS	Ph	**856.23±44.24**	3.60±16.95	**82.16±26.43**
36	GGC	PS	F	**1716.95±87.25**	**–255.00±34.04**	**152.95±50.46**
37	LLL	PS	F	**793.88±90.60**	–33.72±39.75	**–246.83±48.03**
38	LLL	PS	F	**691.96±134.18**	–82.65±58.87	**–274.54±71.14**
39	GGC	PS	F	**1122.74±87.66**	**–179.01±38.46**	**–423.49±46.47**
40	CH	PS	F	**981.00±119.59**	–71.00±52.47	**–386.19±63.41**
41	CH	PS	F	**955.40±237.58**	42.22±102.31	**–375.05±128.66**
42	CH	PS	F	**969.24±238.80**	45.09±102.84	**–386.05±129.32**
43	CH	LLC+PS+GGC	C	**498.32±54.12**	**209.02±17.24**	**–238.78±39.46**
44	CH	LLC+PS+GGC	C	**832.41±55.60**	–21.25±17.71	**–341.71±40.54**
45	CH	LLC+PS+GGC	C	**513.57±30.57**	**47.02±9.74**	**–146.80±22.29**
46	CH	LLC+PS+GGC	C	**802.84±41.84**	12.27±13.33	**–295.01±30.51**

№	Models code			Philip's equation parameters		
	Upper layer	underlying layer	Origin	S	A	B
47	CH	LLC+PS+GGC	C	**606.49±28.60**	**50.18±9.11**	**–150.16±20.85**
48	CH	LLC+PS+GGC	C	**267.68±15.97**	**73.77±5.09**	**–95.58±11.65**
49	CH	LLC+PS+GGC	C	**945.82±63.05**	**–42.66±20.09**	**–394.48±45.97**
50	CH	LLC+PS+GGC	C	**534.39±23.65**	**25.48±7.53**	**–106.98±17.24**
51	CH	LLC+PS+GGC	C	**221.55±19.15**	**130.30±6.10**	4.37±13.96
52	CH	LLC+PS+GGC	C	**334.46±30.83**	**34.43±12.86**	–15.98±17.21
53	CH	LLC+PS+GGC	C	**333.08±22.58**	11.59±9.42	14.24±12.60
54	CH	LLC+PS+GGC	C	**356.31±36.34**	**54.98±15.16**	–36.59±20.29
55	CH	LLC+PS+GGC	C	**112.43±32.20**	**155.44±13.63**	**–39.93±17.62**
56	CH	LLC+PS+GGC	C	**337.78±54.87**	**138.58±23.23**	–59.10±30.02
57	CH	LLC+PS+GGC	C	**256.95±12.07**	**58.89±5.11**	**–93.81±6.60**

Legend: CH – chernozem-like humus mass; GGC – gray-green clay; RBC – red-brown clay; LLL – loess-like sandy loam; KBL – red-brown loam; PS – sand; LLC+PS+GGC –successive layers of relevant soil; F – from agricultural fields; Ph – after phytomeliorative rotation; C – from the career side

The sorptivity of the pedozems (technosol with bulk humus chernozem-like material) depends from the underlying layer (F = 2.06, p = 0.07). If the analysis to remove information about the loess-like loam, the influence of the underlying rocks on the sorptivity loses the statistical significance (F = 0.57, p = 0.68). Thus, the use loess-like loam as underlying layer increases the sorptivity to the level of 746.4 ± 25.8 cm/√hours. The sorptivity is 459.6 ± 18.1 cm/√hours in case of application as underlying layer of all other tested types of substrates. The influence of the underlying rocks on the filtration intensity is statistically significant in a steady state under conditions of use in the upper layer of the chernozem-like mass (F = 13.47, p< 0.01). Most contribute to the increase of the A coefficient such bulk material as the sand (139.3 ± 12.0 cm/√hours) and gray-green clay (145.1 ± 8.5 cm/√hours). Application of complex substrate with successive heterogeneous layers LLC+PS+GGC, which is similar in the properties to the waterproof horizon, reduces the filtration intensity to a level 58.7 ± 3.7 cm/√ hours. Except for specified substrates, the other substrates are not different in its influence on the filtration intensity (F = 0.37, p = 0.69). The application of homogeneous monomodels of chernozem-like mass, or loess-like loam or red-brown clay forms technosols for which filtration rate is 77.4 ± 4.7 cm/√hours.

Constant C describes the dynamics of the infiltration process the early stages of the experiment and is a specific indicator for technosols. In natural soils this constant is zero. In technosols constant C is statistically significantly depends on the characteristics of the underlying substrate in pedozems (F = 7.48, p<0.01). Constant C for sand is not statistically significantly different from zero. Other substrates lead to negative values of constant C. The lowest value of constant C is typical for loess-like loam (–256.9±32.5 cm/√hours). Other substrates do not differ in their impact on this parameter (F = 0.98, p = 0.40). They coefficient C of the modified Philip equation is –105.6 ± 6.5 cm/√hours. Parameters of the modified Philip equation for the water infiltration dynamics of technosols models with gray-green clay in the upper layer are depend from the underlying rock. Sorptivity is statistically significantly higher if the underlying rock is sand compared with homogeneous model (F = 12.94, p<0.001).

Sorptivity of the technosols with sand is 1497.5 ± 58.4 cm/√hours and for homogeneous technosols this constant is 1255.1 ± 33.7 cm/√hours. The considerable sorptivity of the surface substrate composed of gray-green clay allows to quickly get the water during infiltration into deeper layers. The infiltration speed of grey-green clay rapidly decays as a result of water nonresistant structure of this substrate. In technosols, where there is a subsoil layer of sand, the rate of infiltration is maintained at a high level, more time than in monomodels. As a consequence will likely sorptivity of the technosols with sand as the subsoil layer is higher than in the case of monomodels with completely gray-green clay as the subsoil layer.

Sorptivity of the technosols with loess-like clay is statistically significantly depends on the type of subsoil layer (F = 14.85, p<0.001). The difference is statistically significant, depending on the texture of the underlying rock. If the sand as the underlying rock, the sorptivity is significantly higher (771.5±56.6 cm/√hours) than for rock texture which content more clay fraction. The difference of sorptivity between the loess-like loam and technological mixture of the loess-like loam and red-brown clay is statistically not significant (F = 0.01, p =

0.99). Sorptivity for them is 421.1±88.1 cm/√hours. Substrate origin for monomodels affects considerably on the technosols infiltration rate (F = 37.00, p<0.001). Loess-like loam from career side is characterized by much higher sorptivity (585.3±38.1 cm/√ hours) than the substrate after phytomeliorative rotation (256.9±38.1 cm/√hours). Thus, phytomeliorative rotation significantly affects on the water properties of rock. This effect most likely is due to enrich the soil as organic matter in the form of humus and half-decayed organic residues.

Organic components contribute to the formation of aggregate most of which is water resistant. Such formations smooth density variation of clay soil resulting from swelling and shrinkage processes that can maintain stable structure of the pore space. As a result, the soil after phytomeliorative rotation gets such features as reduced infiltration rate, but in-creased level of filtration. The level of filtering, which affects quantitative parameter A in the Philip equation is significantly higher compared to loess-like loam for technosol with sand as the underlying rocks and technological mixture (F = 37.6, p<0.001). Coefficient A for monomodels of loess-like loam is 74.9±12.6 cm/√hours. Coefficient A is statistically significantly not different from zero (–25.8±21.8 cm/√hours) in variant with sand as subsoil layer. This indicates that Philip classic version of the equitation can be applied for simulation of infiltration process this model of technosol. Coefficient A takes a negative value (–73.0±12.6 cm/√hours) for technological mixtures of rocks as underlying layer, indicating that the decay of the filtering process takes place during the entire period of the experiment. In this regard the option of a complete cessation of water filtration can not be excluded.

Thus, the artificial mixture of clay has significant waterproof properties, which ultimately can lead to complete discontinuance of water absorption by technosols. It should be noted that in the state of water saturation of soils are in autumn and winter and early spring, just when there is the greatest rainfall and soil moisture absorption function is essential for storing water to be used during the growing season. Also waterproof properties of soil may increase the risk of water erosion of technosols. The filtration properties of loess-like loam are improved significantly (F = 28.3, p<0.001) after being under phytomeliorative crop rotation. Loess-like loam from career side is characterized by filtering coefficient A 45.4±7.9 cm/√hours and after phytomeliorative rotation this coefficient is set to 104.5±7.9 cm/√hours.

The infiltration dynamic of loess-like loam on the initial stage is substantially depended from the underlying rocks (F = 31.2, p<0.001). The highest value of constant C is reveled for monomodel with loess-like loam (–68.8±16.3 cm/√hours), and the lowest is for model with sand as the underlying rocks (–330.3±28.8 cm/√hours). Origin of the loess-like loam also effects on the value of the coefficient C (F = 252.8, p<0.001). It describes the dynamics of moisture absorption in the first period of the experiment. For soils from career side coefficient C is negative (–176.4±9.6 cm/√hours). This indicates a certain level of "plateau" in infiltration rate that compensates for the extremely high level of infiltration in the early stages. Philip equitation provides infiltration dynamic modeling with monotonous decrease in the rate of water infiltration through the soil surface. This dynamic occurs under conditions of a certain level of stability of soil pore space. For technosoils structural change of the pore space state are inherent in contact with water because hydrolabile units of their structure. Accordingly, during the in-filtration process there are significant changes in the course of the rate of filtration of water. Coefficient C allows Philip equation to be a more flexible. Negative coefficient C indicates that in the infiltration early stages the decay of the water penetration rate into the soil occurs. The positive coefficient C indicates that the first portion of the water is absorbed with extremely high speed, then the process is relevant to the preconditions under which can be described by the Philip equation. Thus, the dynamics of water absorption in the early stages of the process are considerably different for loess-like loam depending on their origin.

Red-brown clay and loam are statistically significantly different in characteristics of sorptivity (F = 19.9, p<0.001). The highest sorptivity is found for red-brown clay from career side (630.2±35.6 cm/√hours). This coefficient is somewhat lower for red-brown clay after phytomeliorative rotation (514.4±35.6 cm/√hours) and is the smallest for red-brown loam (294.3 ± 61.7 cm/√hours). Thus, the clay is more sorptive compared with loam. Being under phytomeliorative crop rotation reduces this parameter.

Parameter A indicating the filtering intensity of technosols. By this measure technosols are statistically significantly different (F = 26.4, p<0.001). The highest filtration rate is characteristic for clay after phytomelioration (128.5±10.4 cm/√hours). A similar value is inherent for parameter of technosols with loam (108.1 ± 17.4 cm/√hours). The lowest coefficient A is fixed for clay from career side (29.8±10.0 cm/√hours). Thus, loam filtration properties are better than clay and phytomelioration can significantly improve the filtration properties of clays and bring them to the level of loam.

The dynamics of infiltration at the start of process is characterized by a parameter C. As it technosems are statistically significantly different (F = 205.5, p<0.001). Reddish-brown loam is characterized by a positive value C (44.2±32.3 cm/√hours). For clay is typical negative value of this parameter. For clay from career side coefficient C is the lowest (–289.1±20.1 cm/√hours), and is little more for clay after phytomelioration (–169.1±20.1 cm/√hours). Negative coefficient C corresponds to an intense process of infiltration, accompanied by sporadic infiltration failure. A positive coefficient is characteristic of the failed infiltration in the first time of experiment.

Conclusion. The study of the water infiltration dynamics from the soil surface is highly informative non-destructive testing for evaluating the properties of the soil body. Studies showed that technosols as artificial creation have fundamental differences between the natural soils for which the classic Philip equitation was proposed. Technosoils are porous, but heterogeneous formations. The process of filtering in technosols is not laminar, periods of smooth water infiltration is outbreak by disastrous water absorption. To simulate this process it was showed that the better results may be obtained due to originally modified Philip equitation. Specific constant C describes the dynamics of the infiltration process the early stages of the experiment and is a specific indicator for technosols. In natural soils this constant is zero. The sorptivity of the pedozems was reveled to be depended from the underlying layer. Organic components contribute to the formation of aggregate most of which is water resistant. Such formations smooth density variation of clay soil resulting from swelling and shrinkage processes that can maintain stable structure of the pore space. As a result, the soil after phytomeliorative rotation gets such features as reduced infiltration rate, but increased level of filtration. The artificial mixture of clay has significant waterproof properties, which ultimately can lead to complete discontinuance of water absorption by technosols. Waterproof properties of soil may increase the risk of water erosion of technosols. For technosoils structural change of the pore space state are inherent in contact with water because hydrolabile units of their structure. Accordingly, during the infiltration process there are significant changes in the course of the rate of filtration of water.

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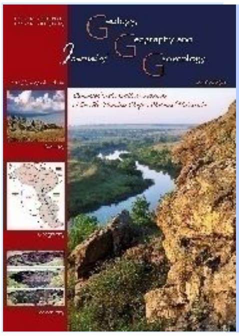

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